UNITED STATES, ATOMIC ENERGY COMMISSION,

Annual Report to Congress

OF THE

U.S ATOMIC ENERGY COMMISSION

FOR

1965 - 67

January 1966

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON, D.C.

LETTER OF SUBMITTAL

WASHINGTON, D.C.,
January 31, 1966.

SIRS: We have the honor to submit herewith the Annual Report of the United States Atomic Energy Commission for 1965 as required by the Atomic Energy Act of 1954.

Respectfully,

UNITED STATES ATOMIC ENERGY COMMISSION,
JOHN G. PALFREY.
JAMES T. RAMEY.
GERALD F. TAPE.
GLENN T. SEABORG, *Chairman.*

The Honorable
The President of the Senate.
The Honorable
The Speaker of the House of Representatives.

Chapter 5

SOURCE AND SPECIAL NUCLEAR MATERIALS PRODUCTION

During the year, negotiations for stretching out uranium procurement deliveries were completed. The AEC's production of enriched uranium and plutonium continued to be cut back consistent with previous announcements and, when the planned reductions are completed in 1969, annual savings in excess of $125 million will accrue. The AEC began implementation of the 1964-enacted law which provides for private ownership of plutonium and enriched uranium.

RAW MATERIALS

Uranium Procurement

The procurement of uranium concentrate (U_3O_8) in 1965 was approximately 4,000 tons of U_3O_8 less than in 1964. The following table shows the sources and quantities for the 2 years:

	Tons of U_3O_8	
	1964	*1965*
USA	11, 850	10, 490
Canada	1, 760	720
South Africa	3, 530	1, 930
Total	17, 140	13, 140

The Canadian and South African contracts, with uncompleted balances of approximately 720 and 1,330 tons respectively, expire in 1966.

Domestic Procurement Program

Negotiations to implement the domestic stretch-out program announced in November 1962 were completed, with signing of the last contract amendment in November 1965. Eleven contracts with 10 companies have been modified, covering the operation of 11 uranium mills through 1970. The total U_3O_8 deferred for delivery in 1967 and 1968 by all producers participating in the stretch-out program is about 15,300 tons, with an equal amount to be delivered during 1969 and 1970. The price for such deferred deliveries through 1968 re-

Chapter 6

THE NUCLEAR DEFENSE EFFORT

Working with the Department of Defense, the AEC continued to provide the Nation a strong nuclear military posture and during 1965 gave a high priority to the maintenance of the four safeguards[1] stated to Congress in 1963 in connection with the ratification of the limited nuclear test ban treaty.

WEAPONS DEVELOPMENT, PRODUCTION, AND TESTS

WEAPONS DEVELOPMENT

During the year, the AEC continued the progressive effort necessary to meet the limited nuclear test ban treaty safeguards requirements and continued the development of weapons designed to meet Department of Defense (DOD) military requirements. The AEC, through its laboratories, continued to participate with the DOD in the research and development of nuclear detonation detection techniques (Vela Program).

Warhead Advances

A major weapons development objective has been the improvement of the penetration capability of strategic missile warheads by further decreasing warhead vulnerability to advanced enemy antiballistic missile countermeasures. Laboratory computations and experiments have identified several possible designs toward achieving these im-

[1] Prior to ratification of the test ban treaty in 1963, the late President Kennedy had announced as U.S. National Policy, four safeguards which would be maintained to provide the Nation with a national defense nuclear readiness posture. The four safeguards were: (1) continuation of an aggressive underground nuclear weapons test program; (2) maintenance of a progressive laboratory program; (3) a readiness capability to resume atmospheric tests if the treaty should be broken by other signatories; and (4) the improvement of our capability, within feasible and practical limits, to monitor the terms of the treaty and to detect violations. The four safeguards were reaffirmed in April 1964 by President Johnson. See p. 55, "Annual Report to Congress for 1963"; pp. 66, 70–71, and 74 of "Annual Report to Congress for 1964."

provements. The designs are under further study, with the purpose of producing—within any given set of limitations in size, weight, and yield—a system with hardness balanced against all possible threats. Field tests to demonstrate the durability of hardened devices have been made and further tests are in preparation.

Significant weapons tests in the areas of nuclear safety and efficiency were also conducted. In addition, the laboratories continued their investigations of advanced concepts and technologies to assure continued U.S. technical supremacy in the nuclear defense field. Efforts to simplify and miniaturize nonnuclear components as well as to reduce weight have been continued.

Progressive Laboratory Programs

The three AEC weapons laboratories—Lawrence Radiation Laboratory, Livermore; Los Alamos Scientific Laboratory, and Sandia Laboratory, Albuquerque and Livermore—continue to function in a healthy and modern condition. The fiscal year 1966 budget (July 1, 1965 through June 30, 1966) provides for continuing progressive laboratory programs in basic nuclear weapons technology, and applied nuclear research and development directed toward stated military requirements. It also provides for continuation of programs to simulate various weapons phenomenology in laboratory environments. The improvement in facilities, the maintenance of challenging research and development programs, and the continuing underground testing program have enabled the laboratories to continue expanding the "state of the art" as well as to retain and recruit the necessary technical staff to conduct the assigned programs.

Included in the laboratory research and development objectives were the design and fabrication of more sophisticated test devices which were used in the continuing underground test program at the Nevada Test Site. In addition, the laboratories maintained and improved their readiness capability to resume atmospheric testing in the event of an abrogation of the limited nuclear test ban treaty by another nation and a subsequent decision by the United States to resume testing in the atmosphere.

The fiscal year 1966 appropriation included almost $13 million for nine major construction projects for the three laboratories (three for Livermore, five for Los Alamos, one for Sandia) with an additional $2.2 million for three support projects at the Nevada Test Site. In addition, equipment and minor construction funds were provided at a level consistent with laboratory needs. This has included upgrading, and additions to, the scientific computer complexes which are considered vital to the development programs at the laboratories.

Neutron Physics Research Using Nuclear Detonations

Two successful neutron physics research experiments in which neutrons from underground nuclear detonations were used as the source for cross-section measurements—utilizing the neutron flight time to define neutron energy—were carried out by the Los Alamos Scientific Laboratory at the Nevada Test Site in conjunction with weapons test events. The technique for these measurements, as it was developed in the past year, permits: (*a*) many experiments requiring high-energy neutrons to be conducted simultaneously; (*b*) high energy resolution, comparable to that available using modern laboratory accelerators; (*c*) recovery of electronic equipment and samples of rare isotopes located near the neutron flight path; (*d*) observations on isotopes too short-lived for conventional laboratory experiments; and (*e*) observations to be made on microgram quantities of materials. Intensity levels in the underground weapon experiments were so great that hundreds of years would be required for acquisition of the same data using laboratory accelerators as neutron sources.

Efforts were directed toward measurements of immediate interest in connection with design and development of weapons and reactors; however, new fission cross-section data were also acquired for the uranium isotopes 233, 235, and 238, and plutonium 239, 240, and 241. Numerous capture cross-sections were also measured. It is anticipated that, as these methods become more highly refined, other unique experiments requiring intense neutron sources will be conducted.

WEAPONS PRODUCTION

Under Presidential authorization, the production of nuclear weapons in 1965 continued to meet the Department of Defense military requirements. Weapon production activities, including fabrication and assembly of new weapons and factory and field modifications of existing weapons, continued during the year with no major problems.

Stockpile Improvement

Weapon production during the year incorporated several design and technological improvements which contribute materially to improved reliability, safety, and efficiency. Efforts to simplify and miniaturize nonnuclear components as well as to reduce weight and increase operational reliability have continued. An additional portion of the stockpile was modified to incorporate devices for prevention of unauthorized use. Improved demolition munitions were introduced into stockpile during the year.

The retirement of obsolete weapons continued on a planned, orderly basis with emphasis placed on re-use and maximum salvage of both nuclear and nonnuclear components and materials for use in current production, research and development, and training programs.

Consolidation of Facilities

The weapons modification centers at Medina Base, San Antonio, Tex., and at Clarksville, Tenn., were scheduled for closure by July 1966 with their functions transferred to the Burlington AEC Plant, Iowa, and the Pantex Plant at Amarillo, Tex.[2] The Clarksville facility (the smaller of the modification centers) was closed in late September 1965 and the facilities made available to the Department of Defense. AEC operations at Medina will be terminated by July 1966 and the facilities will either be transferred to another Federal agency or disposed of by GSA. The termination of these two AEC operations will result in an estimated annual savings of about $3.1 million.

Consolidation of Development Work

In mid-September, a decision was made to consolidate neutron generator development work conducted for the AEC by the General Electric Co. in the GE-Milwaukee Plant, with closely related work at the GE-operated AEC Pinellas Plant in Florida. Savings of over $900,000 annually are estimated when the transition is completed about September 1966.

Transfer of Uranium 235 Fabrication

In late January, the AEC announced the transfer of certain uranium 235 fabrication work from the Rocky Flats Plant, Colo., to the Oak Ridge, Tenn., Y–12 Plant where other similar work was performed. The transfer was accomplished by the end of June 1965; this action is estimated to save up to $1.5 million in future annual operating costs. The Rocky Flats Plant is operated for the AEC by the Dow Chemical Co., and the Y–12 Plant by Union Carbide Nuclear Corp.

Termination of Parts Fabrication at Hanford

In mid-November, the AEC announced the termination of plutonium weapons parts fabrication at the Hanford, Wash., Works by the

[2] See pp. 18–19, 73–74 of "Annual Report to Congress for 1964."

end of 1965. The net savings from this action will amount to over $1 million annually.

Studies of Weapons Production Capacity

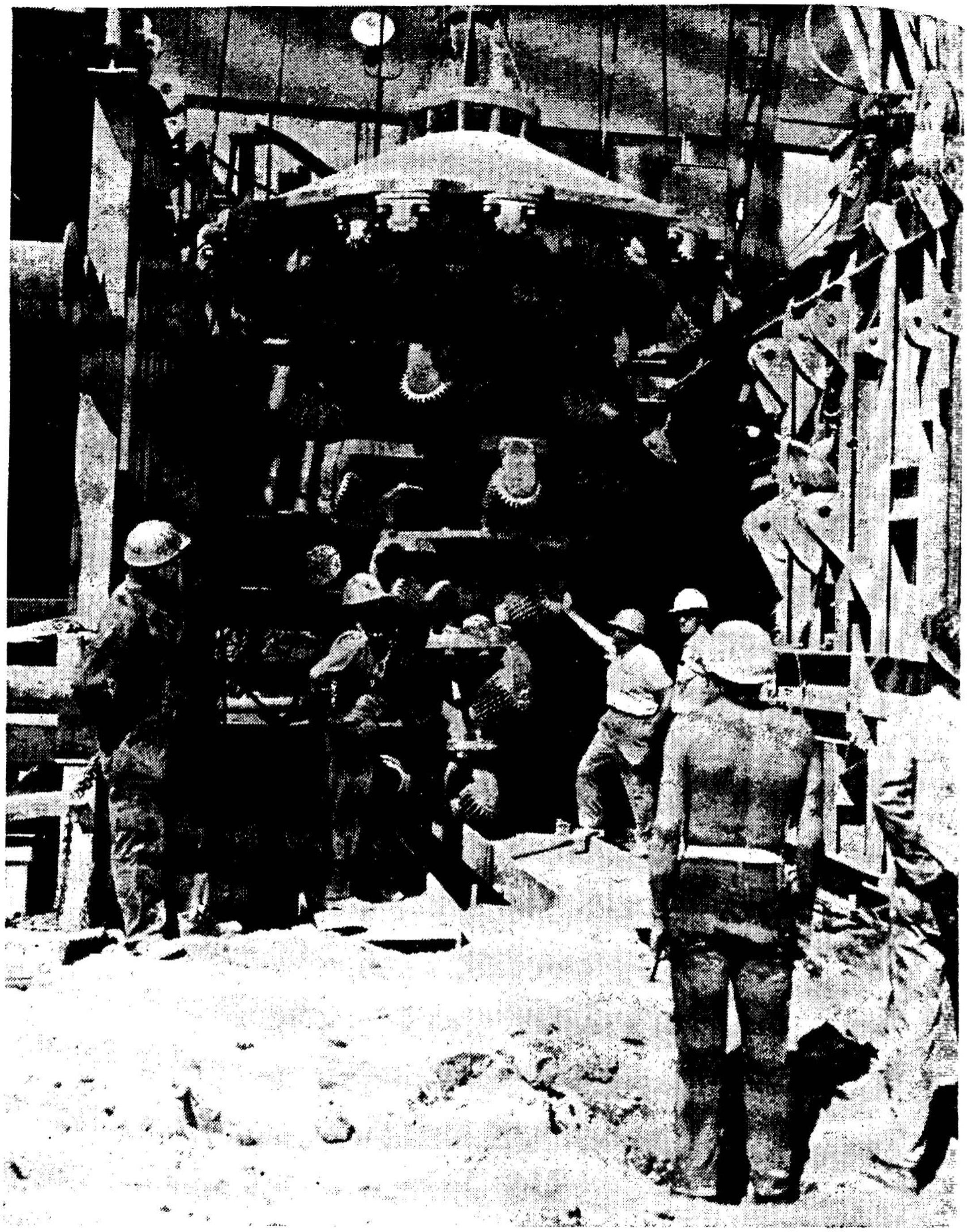
In the interest of economy and efficiency, the AEC is continuing an over-all review of the capacity of plants in the weapons production system. The basic objective of this review is to determine the operating structure and capacity that will most economically assure a capability to meet all foreseeable nuclear weapons needs.

Reduction of Contractor Production Personnel

Employment levels at the AEC's contractor-operated weapons production plants were reduced by approximately 13 percent during 1965. A major reduction occurred at the Bendix Corp., Kansas City, Mo., plant. Early in 1965, it was announced that a reduction from 8,100 employees at the beginning of the year to about 6,700 by yearend would be effected. At mid-year, it was announced that the employment level by year end would be further reduced, to about 6,300. The net reduction was slightly more than 2,000. Other reductions were about 740 positions in the Y–12 Plant at Oak Ridge, about 200 at the Rocky Flats plant, and about 195 at the South Albuquerque, N. Mex., Works.

UNDERGROUND NUCLEAR TESTS

The AEC has continued to conduct an underground nuclear test program at the Nevada Test Site under the terms of the limited test ban treaty since its signing on August 5, 1963, by the United States, United Kingdom, and U.S.S.R. representatives. Through a comprehensive series of underground tests, a sophisticated capability has been developed to support a wide range of full-scale underground experiments. Along with advanced laboratory techniques, new and improved methods continue to be developed for conducting experiments that were not previously considered feasible in the underground test environment (see previous "Neutron Physics Research Using Nuclear Detonations" item).



"*Bigger and Bigger*". The "technology spinoff" from the AEC-Department of Defense underground test program continues to add new equipment and techniques useful to the drilling industry. Laboratory requirements for larger and deeper cased holes during 1965 made it necessary for the Nevada Test Site architectural and engineering services contractor for drilling and mining operations (Fenix & Scisson, Inc., and Petroleum Consultants) to design new equipment and methods and for suppliers to fabricate special equipment. Hugh B. Williams Co. fabricated this 160-inch drill-bit assembly for drilling a hole which required a 144-inch inside diameter casing that had walls 2¼-inch thick. Larger and deeper holes make it possible to conduct underground tests that previously were thought possible only through atmospheric detonations. Under the 1963 limited nuclear test ban treaty, atmospheric detonations are prohibited.

Whetstone-Flint

The current t
1965 and ending
major programs
conducted at th
name of the prec
The planned e
ciple by the Pre
weapons and/or
ments (peaceful
fense effects eve
research and dev
to enhance the U
in the first categ
ment, investigat
reliability and s
outputs and detc
Events, with inc
are planned for
added to NTS
12—The Plowsh
radioactive fallc
of nuclear explo
them special iso
The DOD effects
generated effect
improve the cap
nuclear explosio
As has been t
and approved in
The events are
conducted withi
ban treaty.

Test Event Su

Sixteen events
share event, we
under Whetston
have been anno
December 31, 19

1965 TEST PROGRAM

Whetstone-Flintlock Series

The current test series, Operation Flintlock (commencing July 1, 1965 and ending June 30, 1966), will help to meet the objectives of the major programs of the AEC and DOD through underground tests conducted at the Nevada Test Site. Operation Whetstone was the name of the preceding underground series which ended June 30, 1965.

The planned events of Operation Flintlock, as approved in principle by the President, are grouped into four broad categories: (*a*) weapons and/or device development events, (*b*) Plowshare experiments (peaceful uses of nuclear explosives), (*c*) Department of Defense effects events, and (*d*) joint AEC–DOD tests designed for research and development on improved detection methods and systems to enhance the U.S. detection capability (Vela Program). Included in the first category are events to further weapons and device development, investigate advanced concepts and technologies, assure the reliability and safety of nuclear weapons, and investigate nuclear outputs and detonation effects on weapons materials and components. Events, with increasing magnitudes of yield on a step-by-step basis, are planned for the higher-elevation area of Pahute Mesa which was added to NTS in 1964. The Plowshare experiments (see Chapter 12—The Plowshare Program) are planned to develop "clean" (less radioactive fallout) excavation explosives, and to carry out studies of nuclear explosives designed to produce very high fluxes and with them special isotopes such as those of the transplutonium elements. The DOD effects events are designed to extend knowledge of weapon-generated effects. The joint Vela Program events are planned to improve the capability to detect, identify, and locate underground nuclear explosions.

As has been true in preceding test series, each event was reviewed and approved in accordance with Commission-developed procedures. The events are executed only with the expectation that they can be conducted within the requirements and constraints of the limited test ban treaty.

Test Event Summary

Sixteen events, including four DOD effects events and one Plowshare event, were publicly announced in 1965 as being conducted under Whetstone and 11 events (including a United Kingdom event) have been announced as being conducted under Flintlock through December 31, 1965. Two of the Whetstone announced events were

conducted in the Pahute Mesa area of the NTS. One event was a weapons development event and the other a Plowshare experiment.

Table 1 summarizes the announced 1965 test events.

TABLE 1.—ANNOUNCED UNDERGROUND NUCLEAR DETONATIONS
(January 1–December 31, 1965)

Event name	Date	Type of event [1]
Wool	January 14	Low yield.
Cashmere	February 4	Do.
Merlin	February 16	Do.
Wish Bone [2]	February 18	Do.
Wagtail	March 3	Low intermediate yield.
Cup	March 26	Do.
Kestrel	April 5	Low yield.
Palanquin [3]	April 14	Do.
Gum Drop [2]	April 21	Do.
Tee	May 7	Do.
Buteo	May 12	Do.
Scaup	May 14	Do.
Tweed	May 21	Do.
Petrel	June 11	Do.
Diluted Waters [2]	June 16	Do.
Tiny Tot [2]	June 17	Do.
Bronze	July 23	Low intermediate yield.
Mauve	August 6	Low yield.
Centaur	August 27	Do
Screamer	September 1	Do.
Charcoal [4]	September 10	Low intermediate yield.
Elkhart	September 17	Low yield.
Long Shot [5]	October 29	Low intermediate yield.
Sepia	November 12	Low yield.
Corduroy	December 3	Intermediate yield.
Emerson	December 16	Low yield.
Buff	December 16	Low intermediate yield.

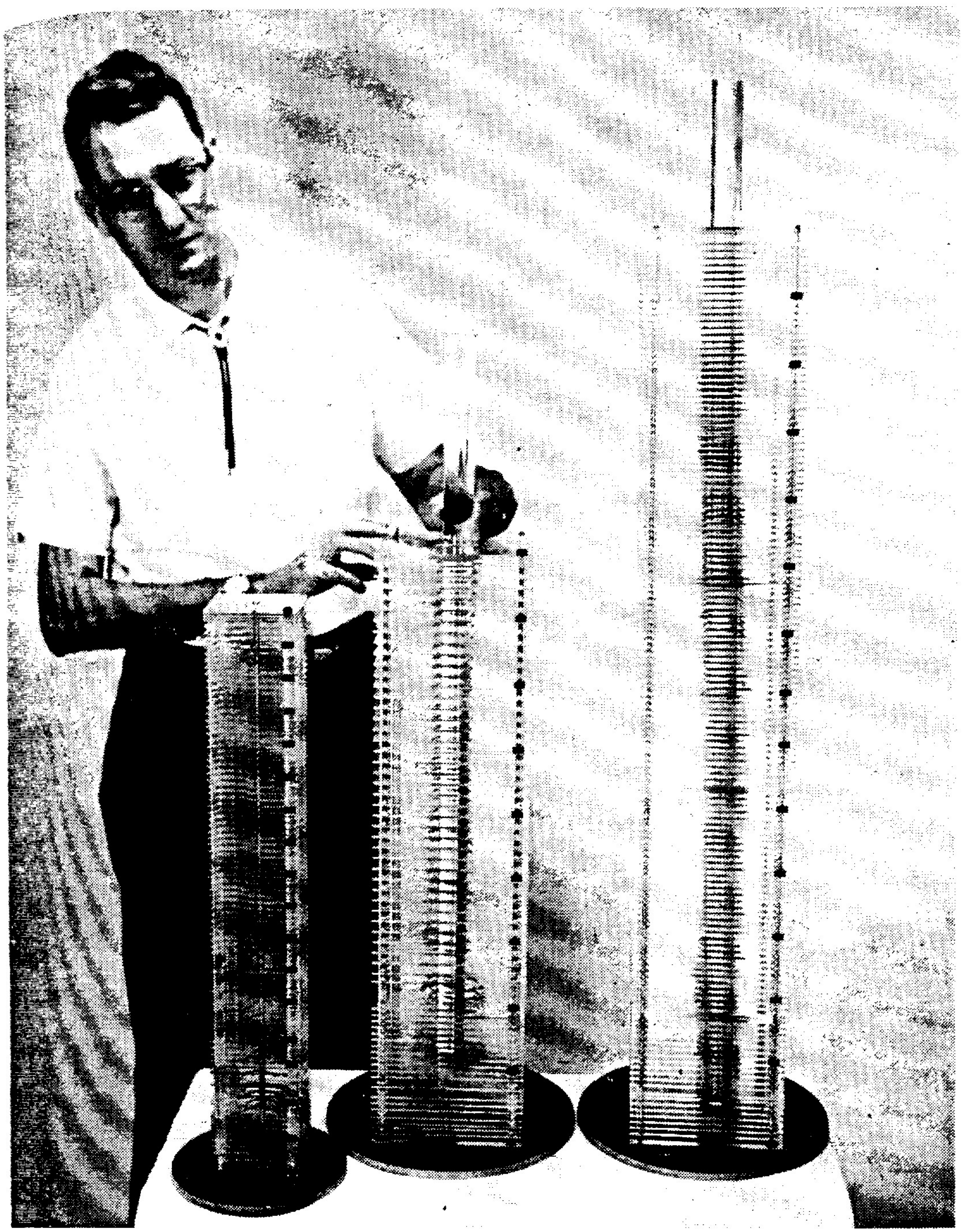
[1] Low yield—less than 20 kt; low intermediate yield, 20 kt to 200 kt, intermediate yield, 200 kt to one megaton.
[2] Department of Defense events conducted with AEC laboratory assistance.
[3] Plowshare (Peaceful Uses of Nuclear Explosives) event.
[4] Jointly with the United Kingdom.
[5] Joint AEC-DOD Vela Uniform event conducted in Aleutian Islands.

"TECHNOLOGY SPINOFF"

Commercial drilling and mining techniques continue to be enhanced [3] by innovations being made at the Nevada Test Site for conducting nuclear detonations deep underground. Some of the new developments that can be adapted by industry are illustrated by photos in this report; another is cited on page 102.

[3] See p. 68, "Annual Report to Congress for 1963"; pp. 11, 67–68, "Annual Report to Congress for 1964."

Important Drillin
at Nevada Test Si
accurate represent
conventional calip
enables engineers t
casing operations
of sonar gear use
walls of the hole
From this film the
structed. These p
any irregularities
(the clear plastic
points areas wher
shown is that of a



Important Drilling Advance. The Dowell sonar caliper survey tool developed at Nevada Test Site during 1965 provides drilling engineers with a much more accurate representation of large-diameter drilled holes than was possible with conventional caliper logs. By revealing potential areas of difficulty the system enables engineers to carry out remedial work when it is most economical—before casing operations commence. The tool is an adaptation of the familiar type of sonar gear used in submarine detection. A rotating sonar beam scans the walls of the hole and transmits a trace of its findings to a photographic film. From this film the scale models of the hole shown in the above picture are constructed. These provide a pictorial representation of the drilled holes, showing any irregularities or deviations and enable scale models of the casing string (the clear plastic tubes shown in the picture) to be run in the hole. This pinpoints areas where remedial work is needed. The tallest of the three models shown is that of a 4,200-foot-deep hole drilled and cased on Pahute Mesa.

"Lost" Equipment Recovery

An additional new technique, developed during 1965 and of interest to the drilling industry, is an integrated television circuit and remote manipulator for down-hole equipment recovery.

The television-manipulator system provides a means of recovering drill bits, drill pipe, and other equipment or material which have broken loose in down-hole drilling operations. The system includes a closed television circuit (previously developed at NTS for down-hole use) to provide a view of conditions in a hole whether in dry soil or underwater, and to facilitate operation of the remote manipulators which can lift up to 26,000 pounds.

When a drill bit, cutter, drill pipe, or other piece of equipment breaks loose during down-hole drilling, it is necessary to "fish" for the equipment with various mechanical devices. For the most part, "fishing" operations are conducted blindly. Frequently, they take long periods of time and occasionally it has become necessary to cease drilling entirely because of the inability to clear the hole. Drilling technicians believe development of a means for "seeing" conditions down-hole and for moving, gripping, and lifting "lost" equipment with sensitive manipulators will be more efficient and more economical (both as to time and cost) than the "fishing" techniques ordinarily used by the drilling industry.

ATMOSPHERIC TEST READINESS CAPABILITY

As directed by the late President Kennedy and reaffirmed in April 1964 by President Johnson, the AEC continued to maintain and improve the capability for resumption of nuclear testing in the test ban treaty prohibited environments (atmosphere, underwater, and in space) should it be directed to do so in the event of an abrogation of the treaty or in the interest of national security, within a minimum reaction period. This capability was attained on January 1, 1965.

Summary of Major Readiness Accomplishments

The following major projects have been accomplished and are being maintained in a state of readiness: (*a*) substantial upgrading of facilities at Johnston Atoll, the base of operations for the majority of any planned tests; (*b*) construction of scientific and support facilities throughout the Hawaiian area and at Johnston Atoll; (*c*) modification and instrumentation of three C–135 aircraft to permit basic measurements of device diagnostic data and phenomena for the AEC; (*d*)

modification and instrumentation of RB–57 aircraft for debris sampling purposes; (*e*) availability of additional B–57 aircraft for launching airborne rocket samplers; (*f*) availability of B–52 aircraft for use as device drop aircraft; (*g*) development, fabrication, and stockpiling of special ballistic cases for nuclear devices; (*h*) establishment of the capability for a high altitude program by development of booster vehicles as device carriers, and small instrumentation rockets; (*i*) comprehensive instrumentation development to establish advanced equipment designs which can perform reliable and accurate measurements of device outputs and weapons effects; and (*j*) identification of operational systems tests as well as nuclear tactical exercises of prime interest to the services and the development of plans and safety studies required to place them in readiness.

In addition, full-scale and abbreviated air-array exercises of a nonnuclear nature to check the diagnostic capability, based on Johnston Atoll and in the United States, respectively, have been conducted and are planned. These help to maintain a state of readiness by increasing the technical proficiencies of both air crews and civilian technicians, as well as to test and exercise the diagnostic aircraft and the instrumentation.

AEC/DOD Agreement on Johnston Atoll

The Commission and the Department of Defense, in February 1965, entered into an agreement regarding contractual arrangements at Johnston Atoll. The principal points are:

(*1*) A single contractor, operating under one contract, will provide engineering, construction, maintenance and operations support services at the Atoll.

(*2*) Except for contract administration, which remains an AEC responsibility, the Commander of DOD's JTF–8 (Joint Task Force No. 8) will exercise operational control.

The DOD assumed base construction, maintenance, and operations costs on July 1, 1965. Through appropriate delegation of authority and coordination, the operational requirements were merged with the contract administration which is being accomplished by the AEC.

Establishment of Honolulu Area Office

The AEC's Honolulu Area Office was established on May 1, 1965, to increase the efficiency and economy of operations in connection with the administration of Pacific operations. These activities, previously carried out both in Honolulu and Las Vegas, Nev., involve adminis-

tration of contracts for engineering, construction, and operations support services related to test readiness in the Pacific Area.

Participation in Solar Eclipse Expedition

Los Alamos and Sandia diagnostic aircraft participated in a National Science Foundation expedition (based on American Samoa) to the South Pacific Ocean area to make observations of the exceptionally long-duration total solar eclipse on May 30, 1965. The participation was preceded by an AEC determination that no adverse effect would result to the readiness posture and that such an experiment would provide additional valuable training for both the flight crews and civilian technicians. Solar and astrophysical phenomena are areas of interest to the AEC in view of their special connection with both the Vela satellite and surface-based detection programs. In addition to aircraft participation, during the eclipse, Sandia launched several rockets, from a base on the island of Rarotonga in the Cook Group, carrying LASL-developed X-ray detectors to observe X-ray fluxes from the partially-obscured sun.

The scientific commander of the Los Alamos-Sandia expedition reported that about 85 to 95 percent of the possible total data was obtained and that essentially all equipment operated satisfactorily. Shortly after the eclipse, the two diagnostic aircraft flew to Australia, from where missions were flown to obtain cosmic ray data in the vicinity of the south magnetic pole. The aircraft returned to their home base in the United States in early June.

DETECTION OF NUCLEAR EXPLOSIONS

The AEC continued in 1965 to participate in studies on ways and means to improve detection techniques and systems (Vela program) for both underground and space nuclear explosions. The Vela program is supervised by the Advanced Research Projects Agency (ARPA) of the Department of Defense and is a research and development effort conducted to improve capabilities of detecting, locating, and identifying nuclear detonations. The ultimate objective is development of a system, or systems, capable of adequately monitoring a comprehensive nuclear test ban by (*a*) detection of underground detonations; (*b*) detection, by means of satellites, of nuclear explosions in space; and (*c*) detection of nuclear explosions in space through ground detection equipment.

VELA UNIFORM PROGRAM

During 1965, measurements of ground shock accelerations and other effects, and the operation of both short- and long-range seismic recording stations continued, in conjunction with underground test events at the NTS as a part of the Vela Uniform program (underground test detection). The DOD has the administrative, funding, and technical responsibility for the program, and the AEC is responsible in connection with certain nuclear events, for: (*a*) conducting the experiment within the provisions of the limited test ban treaty; (*b*) assuring public safety; (*c*) constructing emplacement facilities and firing; (*d*) determining the yield and conducting post-shot drilling; and (*e*) instrumenting for close-in measurements.

Three underground events have been conducted under the Vela Uniform program. The first was Project Shoal, a nuclear detonation of about 12 kilotons (kt) in granite, conducted on October 26, 1963, near Fallon, Nev.,[4] to record seismic signals from a nuclear detonation for comparison with signals generated by a naturally occurring earthquake. The second was the October 22, 1964, Salmon event of Project Dribble,[5] in salt at the Tatum Salt Dome, near Hattiesburg, Miss., directed at exploring decoupling [6] techniques. The third event was Long Shot conducted on October 29, 1965, on Amchitka Island in the Aleutian Chain.

Project Dribble

The primary technical objectives of Project Dribble were to obtain data which can be extrapolated to indicate the significance of decoupling at the five kiloton level and to study seismic wave propagation in the southeastern United States.

During 1965, following investigation of the Salmon cavity, the Dribble site was placed on a standby-ready status. Currently, there is a DOD-approved program for re-entry into the Salmon cavity through the emplacement casing. The purpose of this project is to determine whether the Salmon emplacement hole can be used again in the event that a decision is made to request permission for another

---

[4] See p. 70, "Annual Report to Congress for 1963"; p. 75, "Annual Report to Congress for 1964."

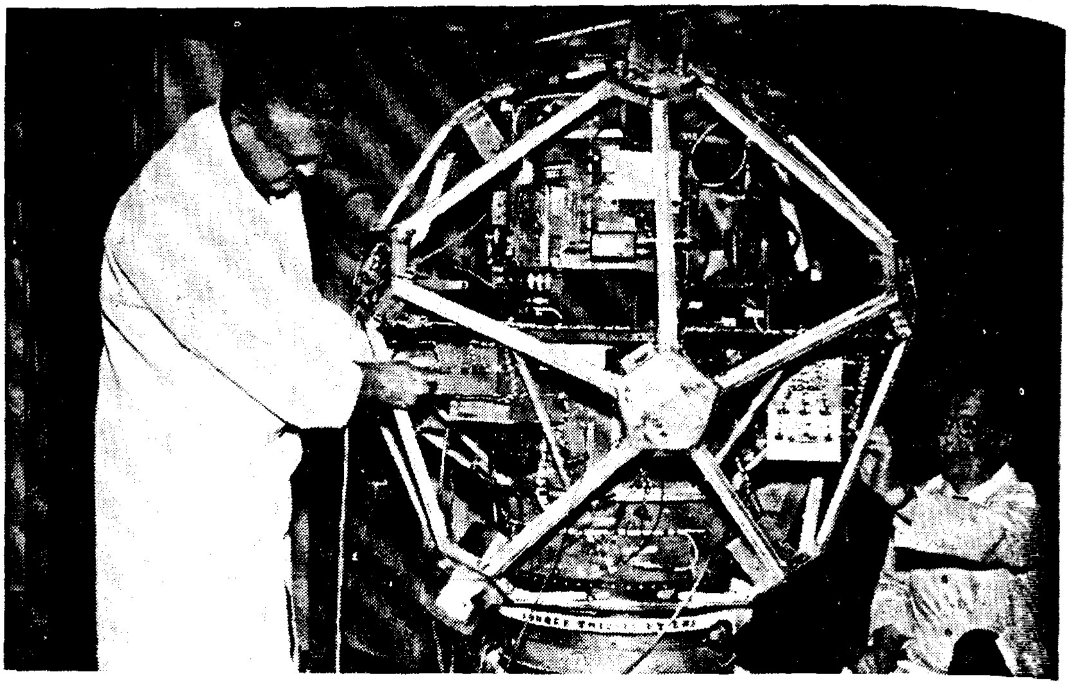
[5] See pp. 75–76, "Annual Report to Congress for 1964."

[6] "Tamped" is the placing of an explosive device underground in direct contact with the medium in which it will be fired so that the shock and earth movement generated by the explosion will be directly transferred by close physical coupling to the medium.

"Decoupled" is the use of an underground cavity as an explosion site to reduce the transference of the explosive energy and hence the amount of shock and earth movement imparted to the surrounding medium, thus possibly concealing the true magnitude of the explosion or reducing the effects of the explosion below the detection capabilities of a detection system.

DOD experiment. Real estate lease agreements on the Dribble site are being maintained.

Salmon post-shot investigation. Following the 1964 detonation of the 5-kt Salmon event in a 2,700-foot hole, a 2-month waiting period was requested by the Advanced Research Projects Agency to allow unhampered surface investigations. Postshot drilling was started in early January 1965 and the cavity was penetrated in early March. The cavity was about 112 feet in diameter with the bottom 24 feet filled with solidified melt and with a void volume of about 690,000 cubic feet. The temperature was 400° F., about 280° hotter than before



Space Detonation Detector. Vela research satellites use Sandia Laboratory-designed logic systems and Los Alamos Scientific Laboratory-designed detectors for the detection of nuclear devices detonated in space. The third set of Vela satellites was placed into orbit some 60,000 miles in space during July. A world-wide tracking network tapes data from the satellites. The tapes are processed by Sandia Laboratory and the reduced data are sent to Los Alamos Scientific Laboratory for final analysis. Photo *above* shows a satellite being readied for testing at Sandia Laboratory before being encased in its sheath and shipped to Cape Kennedy, Fla., for boosting into space. The satellites measure 54 inches in diameter, weigh about 500 pounds, and are icosahedron (20 sides) shaped. Each of the triangular sides is covered with solar cells which draw energy from the sun for operation of all internal electronic equipment. A central cylinder houses the orbit injection rocket and provides structural rigidity. X-ray detectors are at the corners of the spacecraft. Neutron and gamma radiation detectors are located inside the satellites. It is believed that the sensors will allow detection of nuclear tests conducted in space more than ten million miles from earth. In photo *opposite page* S. P. Schwartz, Sandia Corp. president, shows a satellite model to representatives of the All-Pueblo Council, Mescalero and Jicarilla Apache Tribes and Navajo Tribe, who visited the AEC's Sandia Laboratory in May. The purpose of the program was to brief the Indian officials on the nature of Sandia's work and employment opportunities and practices at the Laboratory.

the shot. Livermore scientists responsible for the technical programs believe the temperature will decline slowly. At the time penetration was made into the cavity, radioactivity had declined to about one-tenth of a roentgen per hour, and the cavity gases were under a vacuum of 20 inches of mercury.

Salmon claims. The AEC, as part of its responsibilities in connection with conduct of the Salmon event, handles investigation and settlement of claims pursuant to the provisions of paragraph 167 of the Atomic Energy Act (reimbursable to the AEC by the Department of Defense). In early 1965, payments of claims beyond 12 miles from ground zero of the Salmon event were deferred until detailed studies by technical consultants could be made of the ground structure and seismic propagation. The studies were completed in mid-1965 with a conclusion that the previously stated thresholds of damage criteria (based on chemical explosions) were not applicable in the case of Salmon. A number of factors such as local geological features, energy propagation phenomena, orientation of buildings, and preshot stress conditions were recognized as significant in specified individual cases. The studies did not identify any single cause for damage. Claims of $5,000 or less are now being settled when supporting evidence shows that the damage claimed had directly resulted from the Salmon detonation.

Long Shot

Long Shot was the third joint AEC–DOD Vela Uniform nuclear event and was executed on October 29, 1965. The experiment was con-

ducted deep underground on Amchitka Island in the Aleutian Chain and was fully contained. Preliminary results indicate that a seismic magnitude of about 5.75 (moderate) was achieved. The event had worldwide seismic coverage. News media representatives were present on Amchitka before and after the detonation. The objective was to obtain a new set of seismic travel-time curves from an underground disturbance in a high-incidence earthquake area. The AEC participated by: (*a*) furnishing, timing, and firing the nuclear device; (*b*) constructing emplacement facilities; (*c*) supervising emplacement of the device and stemming the hole; (*d*) developing and directing the public safety program; and (*e*) assuring that the experiment was carried out in accordance with the provisions of the limited nuclear test ban treaty.

Unmanned Seismic Observatory (USO)

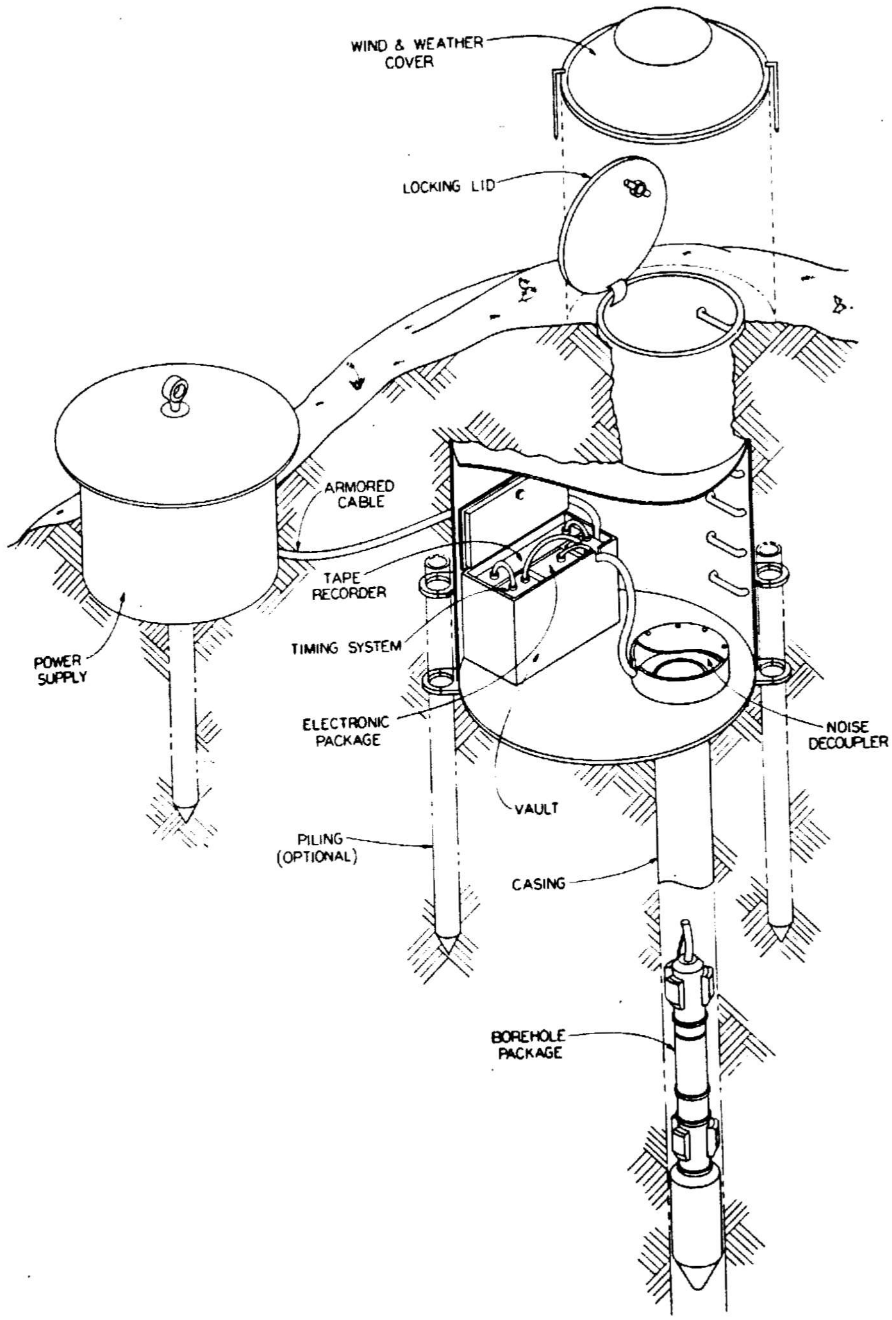
A prototype model of an unmanned seismic observatory is being developed for the Advanced Research Projects Agency by the AEC's Sandia Laboratory. Initial field test of a prototype unit is expected to begin in February 1966 near Albuquerque, N. Mex., with field tests of production units in Alaska (Arctic environment) beginning in April, and in Utah (Uinta Basin Seismological Observatory to correlate data with that from a well-instrumented site) beginning about July 1966.

The project, which was authorized in 1964, calls for development of a compact, reliable system capable of operating unattended for a minimum of 90 days (120 days now appears feasible). For a given station, the planned timing accuracy is 0.1 second or better over the operational period. The system is to continuously record three components of short- and long-period seismometer outputs and is planned for operation under the extremes of normal terrestrial environments.

The present design concept envisions a USO in three equipment units—to provide flexibility—consisting of: (*a*) down-hole unit consisting of three short-period seismometers and three long-period seismometers; (*b*) an electronic package including electronic logics, tape recorder, timing system, etc.; and (*c*) a thermoelectric power supply.

VELA SATELLITE DETECTORS

The AEC continued to participate in the Vela satellite program, a research and development effort to develop satellite-based instruments and detection systems for the detection of nuclear explosions conducted in space.



Unmanned Seismic Observatory. The schematic drawing shows how an unmanned seismic observatory, now under development for the Department of Defense by the AEC's Sandia Laboratory, would appear in a typical underground installation. The borehold package is positioned inside the pipe by a gyro unit and mechanically locked in place. The center section of the package rotates to aline short-period seismometers to compass points; long-period seismometers are in lower section with stabilizing weight. The first prototype unit is scheduled to undergo field testing near Albuquerque, N. Mex., early in 1966.

Third Pair Orbited

Another successful Atlas-Agena launch on July 20, 1965, placed the third pair of tandem AEC-instrumented satellites into widely-spaced positions on a near circular orbit with average radius of about

60,000 nautical miles. The newest pair of nuclear test detection satellites joined the four satellites placed in similar orbits by two earlier launches in October 1963 and July 1964. Improved types of detectors designed by Los Alamos Scientific Laboratory, and new integrated circuits for the logic systems developed by Sandia Corp., are aboard the twin detection satellites. The six spacecraft contain radiation detectors for neutrons, gamma rays, and X-rays. The second and third launch satellite contained instrumentation for measuring characteristics of the "solar wind" in interplanetary space, charged particle fluxes as seen in the "magnetosphere" and "transition" regions of space, and solar X-rays so that the effects of these background radiations can be evaluated and understood. In addition, the third launch satellites were also instrumented to obtain data on lower energy solar X-rays.

All spacecraft are performing their nuclear test monitoring functions as intended. Although there have been failures of some components in certain detection systems, these have not appreciably affected the detection capabilities of the spacecraft because of the electronic circuit and sensor redundancies incorporated into the payloads. A fourth Vela satellite launch is scheduled for late 1966 to place two additional AEC-instrumented satellites into orbit with further improvements and augmented capabilities. In addition to the currently authorized satellite launches, AEC-developed instruments to measure solar X-ray emision were flown on low-altitude rocket probes.

VELA GROUND DETECTORS

The AEC continued to participate in the program for the ground-based detection of nuclear explosions in space. The primary effort was on the air fluorescence method. The fluorescence system is based on the detection of the fluorescent light produced when nitrogen is bombarded by X-rays.

Efforts were directed toward five general areas: (*a*) analysis of air fluorescence data obtained from the Dominic atmospheric weapons test series [7] of April-November 1962, (*b*) studies of the energy partition into various frequency bands, (*c*) calculations on the effects of atmospheric attenuation on air fluorescence signals received on the ground, (*d*) investigation of the charge transfer processes that occur under high altitude conditions, and (*e*) conduct of a joint AEC-DOD summer lighting study to investigate lightning backgrounds as they

[7] See pp. 62–68, "Annual Report to Congress for 1963."

may relate to air fluorescence detection; the experimental phase of this study was conducted during the summer at Los Alamos and data analyses are underway.

MUTUAL DEFENSE AGREEMENTS

Under the provisions of the Atomic Energy Act of 1954, as amended, the President may authorize the United States to cooperate with another nation or regional defense organization to which the United States is a party and to communicate certain classified data as is determined necessary for mutual defense purposes.[8] During 1965, exchanges of information for mutual defense purposes continued under 11 such agreements with Australia, Canada, Belgium, France, the Federal Republic of Germany, Greece, The Netherlands, Turkey, Italy, the North Atlantic Treaty Organization (NATO), and the United Kingdom. The agreement with the United Kingdom is much broader than the other 10, and includes the exchange of weapons design information through visits and reports and the exchange of nuclear materials. A revision of the agreement with NATO, submitted to the Congress on June 30, 1964, became effective during March 1965 upon approval by all member nations of NATO.

[8] See pp. 77 and 79, "Annual Report to Congress for 1964."

795-958—66——9

Chapter 12

THE PLOWSHARE PROGRAM

Progress in the AEC's Plowshare program to develop peaceful applications for nuclear explosives can be viewed as resulting from three separate but interrelated efforts: Research and development in the laboratory, field experiments, and studies and demonstrations of applications in conjunction with groups which would make use of nuclear explosives. During 1965, advances occurred mainly through studies and development of plans for Plowshare applications and through research and development based on data gathered during the year from seven 1964 field experiments and from experiments conducted in other programs such as the AEC–DOD Vela Uniform Salmon event. Only one Plowshare field experiment, a cratering experiment called Palanquin, was conducted in 1965.

Companies in the natural resources fields are becoming increasingly interested in contained nuclear explosions for underground engineering applications. Several companies are evaluating the possibilities for the use of nuclear explosives in their operations. As a result of such evaluations, the El Paso Natural Gas Co., Kennecott Copper Corp., and the Columbia Gas System Service Corp. have joined with the AEC in feasibility studies of applications.

POSSIBLE APPLICATIONS

UNDERGROUND ENGINEERING

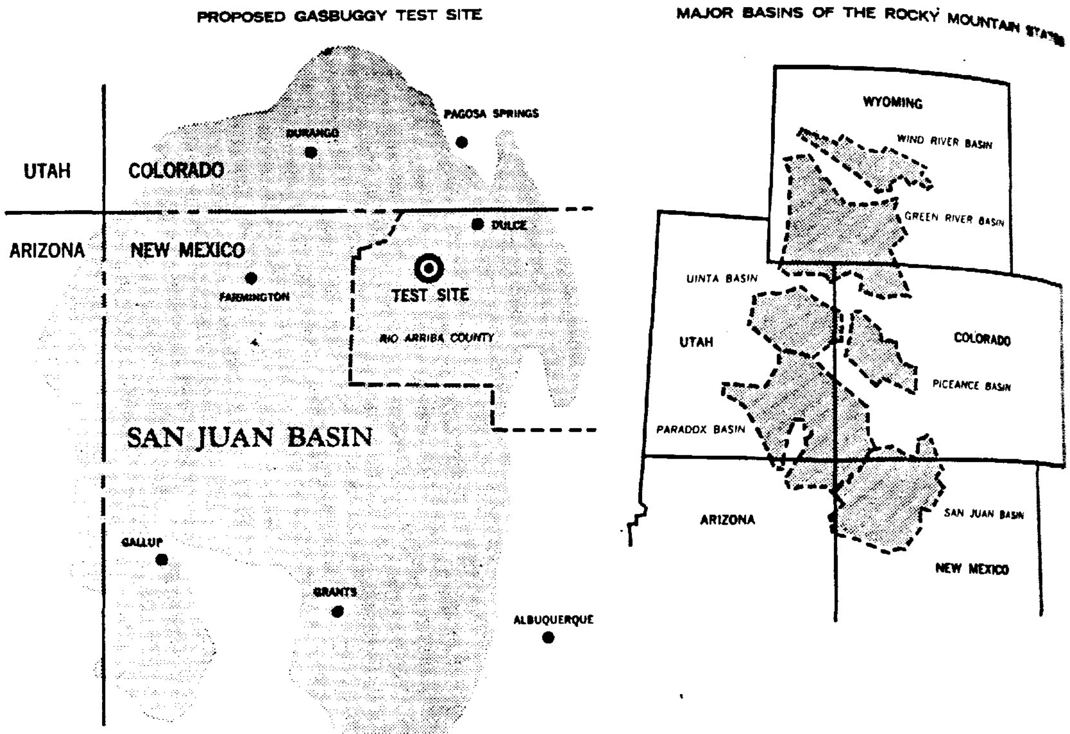
The underground engineering category of applications mainly involves contained nuclear explosions to fracture rock for a variety of industrial purposes, such as stimulating production of natural gas and oil; storing natural gas, other products, or wastes; and mining minerals by leaching or block caving. During 1965, a preliminary feasibility study of natural gas production stimulation was completed. Two other studies were begun on copper leaching and natural gas storage. The preliminary feasibility study of natural gas production stimulation resulted in a proposal from the El Paso Natural Gas Co.

795-958—66——14

of El Paso, Texas, for undertaking jointly with the AEC, the experiment, called the Gasbuggy, proposed by the study group. These activities grew out of work that has been underway for several years with industry and other Government agencies, particularly the U.S. Bureau of Mines.

The Commission's policy of cooperating with industry in developing peaceful uses for nuclear explosives was most recently expressed by Chairman Seaborg on January 5, 1965, during hearings on the Plowshare Program before the Joint Committee on Atomic Energy when he said:

> "We believe that we now have enough data on underground engineering to warrant undertaking a demonstration project in cooperation with industry. We have had numerous discussions with several companies about possible joint projects. Our next step in this area will probably be guided by these interests." [1]



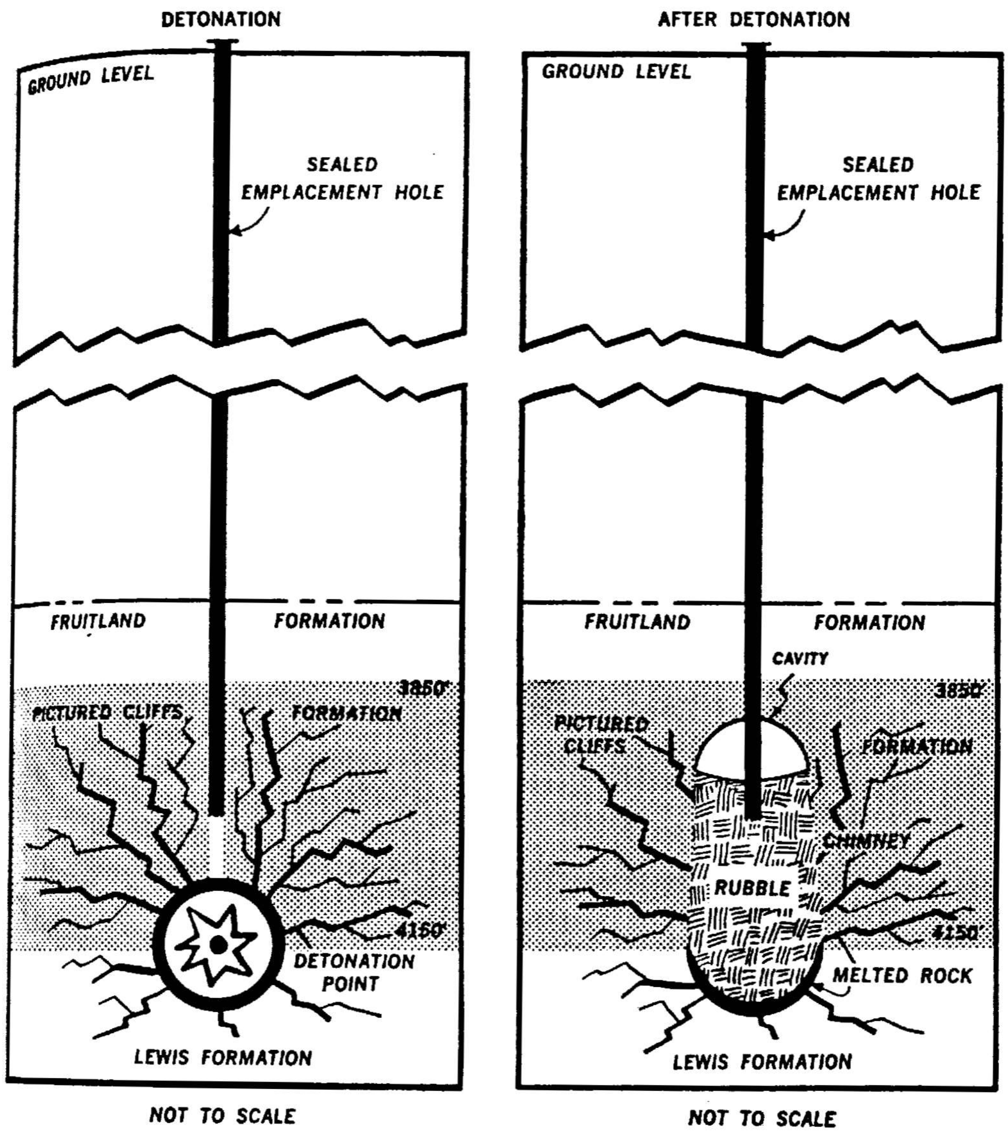
Gasbuggy Location. If nuclear fracturing proves commercially feasible for increasing production from a natural gasfield in the San Juan Basin (*left* above), it might be employed to great advantage in the other Rocky Mountains natural gas-producing fields (*right* above) which contain certain similar gas-bearing formations. Fracturing refers to cracking the formation rock to induce greater production. For best results from nuclear stimulation, a reservoir should be too "tight" for conventional methods of fracturing to be of much value, and thick enough to absorb the full effect of the nuclear explosion. An experiment, Project Gasbuggy, in the San Juan Basin was recommended in a report made by a study group comprised of representatives of El Paso Natural Gas Co., the San Francisco Operations Office of the AEC, and the U.S. Bureau of Mines.

[1] "Peaceful Applications of Nuclear Explosives—Plowshare," hearing before the Joint Committee on Atomic Energy, January 5, 1965; available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402, $2.

Project Gasbuggy

After 18 months of study, a technical group composed of representatives of the El Paso Natural Gas Co. (EPNG), the AEC San Francisco Operations Office (SAN), and the U.S. Bureau of Mines (USBM), assisted by the Lawrence Radiation Laboratory (LRL), Livermore, Calif., reported on May 14, 1965, their conclusion that

PROPOSED PROJECT GASBUGGY EXPERIMENT
PREDICTED UNDERGROUND EFFECTS



Gasbuggy Concept. The simplified drawings illustrate the anticipated effects of a nuclear explosion deep in the earth. Such an explosion has been proposed for Project Gasbuggy as a means of increasing production from a natural gasfield. At the moment of detonation (*left*), the explosion creates a giant cavity and fractures the rock in all directions. Shortly afterward (*right*), the ceiling of the cavity collapses, resulting in a rubble-filled "chimney." On June 17, the El Paso Natural Gas Co. (EPNG) proposed that Project Gasbuggy be carried out as a joint AEC-EPNG project.

the effects of a contained underground nuclear explosion could substantially increase the production of natural gas from low-permeability geologic formations. A specific gas reservoir formation of low productivity was chosen by the group for analysis to determine whether a field test was feasible and desirable. The analysis indicated that the effect of the explosion might well have a beneficial effect upon the producing characteristics of the formation. Estimates based largely upon anticipated fracturing effects indicate that production rate and producible reserves will be greatly increased by this treatment, thereby providing the means by which the natural gas resources of the United States could be more effectively exploited.

Subsequently, on June 17, EPNG proposed to the Commission that Project Gasbuggy be carried out as a joint experiment to obtain further data and to test specifically the effect of the explosion on the production of gas. After an extensive review of this proposal, the AEC has developed a concept for the experiment which would involve the detonation of a 20-kiloton nuclear explosive some 4,200 feet underground in an area about 55 miles east of Farmington, N. Mex. The company and USBM would participate in the evaluation of the effect of the experiment on the production of natural gas. In addition, the company would provide such things as an existing gas well on the site, geologic and production data, technical personnel, certain supporting services, and would assume the risk for damage to their neighboring property. If the experiment were carried out it would be the first use of a nuclear explosive for industrial purposes anywhere in the world.

Although the Commission has concluded Gasbuggy would be a valuable technical experiment in the development of the technology for the peaceful application of nuclear explosives, funds are not presently expected to be made available to the AEC in fiscal year 1967 to proceed with the experiment.

Other Underground Engineering Applications

Project Ketch. Based upon a general economic appraisal of gas storage in underground fractured zones made by nuclear explosions, the preliminary review of data on the volume of space made available by a nuclear explosion, and studies of the ability of the zone to hold pressure, the Columbia Gas System Service Corp. (CGSSC) has suggested a more detailed examination of this application. For this purpose, another feasibility study group has been formed with personnel from the CGSSC, SAN, and LRL. Since the technical feasibility of this application, called Project Ketch, depends greatly on the specific geologic formation involved, the group will carefully

examine alternative, specific locations. The locations being examined are within the central portions of Columbia's service territory which includes parts of New York, Pennsylvania, Ohio, Maryland, West Virginia, Virginia, and Kentucky. The AEC's Nevada Operations Office will also participate in the preliminary study. This application is dependent upon the availability of appropriate geologic formations: a tight competent rock which would hold the gas in the nuclear chimney under pressure, or a permeable formation with a tight cap-rock in a suitable geologic structure.

Project Sloop. Technical studies, which have been underway for several years of *in situ* leaching of copper from low-grade ore fractured by nuclear explosions, reached the point during the year that the Kennecott Copper Corp. joined with the AEC and USBM in a specific preliminary feasibility study of this application, called Project Sloop. A study group was formed of personnel from Kennecott, SAN, USBM, and LRL to consider the feasibility of this application in the context of specific ore bodies, *e.g.*, a Kennecott-owned deposit near Safford, Ariz. The group is considering available data and will determine whether an experiment is necessary to acquire additional data. If so, the group is expected to propose a preliminary concept for such an experiment. The Oak Ridge National Laboratory is making a preliminary assessment of the feasibility and costs of processes which might be necessary to remove radioactivity from the processing plant. It is expected that the study will be completed during 1966.

Other applications. Discussions are continuing with other companies and groups to determine their interest in participating with the AEC in studies of other applications in the specific technical and economic framework of the user. (Progress in research and development related to these applications is described later in this section under the heading "Contained Explosions.") Applications of particular interest to AEC for detailed examination are waste disposal, recovery of oil from oil shale, and block caving mining applications.

EXCAVATION

When nuclear explosives are detonated underground at an appropriate depth, they excavate earth, leaving a crater useful for engineering purposes, *e.g.*, canals, harbors, or cuts for roads. Although the basic principle of explosive excavation has been demonstrated, a development program, consisting of several experiments,

is considered necessary before the precision required for large engineering projects using explosives in high nuclear yield ranges can be undertaken. (The progress and status of this development program is discussed in a later section of this chapter entitled "Excavation Program.") Sufficient data now exist so that several projects have received preliminary study or are being studied. There were no further activities in 1965 in connection with Project Carryall[2] in view of the present incompatibility of the pace of the nuclear excavation development program and the interstate highway construction program.

Interoceanic Canal

Pursuant to Public Law 88–609, the President appointed, on April 18, 1965, a Commission to "make a full and complete investigation and study, including necessary onsite surveys, and considering national defense, foreign relations, intercoastal shipping, interoceanic shipping, and such other matters as they may determine to be important, for the purpose of determining the feasibility of, and the most suitable site for, the construction of a sea-level canal connecting the Atlantic and Pacific Oceans; the best means of constructing such a canal, whether by conventional or nuclear excavation, and the estimated cost thereof."

The Atlantic-Pacific Interoceanic Canal Study Commission has selected the Chief of Engineers, U.S. Army, as its Engineering Agent to conduct an Engineering Feasibility Study of three sea-level routes: The present Canal Zone, the Darien Region of Panama, and northwestern Colombia. The Engineering Agent will coordinate the activities of the Corps of Engineers, the AEC, and the Panama Canal Co. in this study. The AEC is responsible for collection and evaluation of data on meteorology, high altitude winds and temperatures, seismic wave propagation and structural response, and the land and sea environments. The Environmental Science Services Administration (which includes the U.S. Weather Bureau and the U.S. Coast and Geodetic Survey), the Sandia Laboratory, the Columbus, Ohio, laboratories of the Battelle Memorial Institute, and other specialized groups under contract to AEC will be responsible for implementing these programs. The AEC's requirements for data will be established by technical working groups, under the AEC's Nevada Operations Office. These groups will include scientific personnel from the Lawrence Radiation Laboratory, Livermore, the primary data collection agencies, and other expert groups.

[2] See pp. 164–165, "Annual Report to Congress for 1964."

In addition, similar technical working groups have been established by the Corps of Engineers to develop technical criteria for nuclear excavation and engineering aspects of a sea-level canal. These groups will make use of data acquired from the AEC's nuclear excavation program. The Canal Study Commission, in its first annual report, pointed to the vital relation between data from further nuclear excavation experiments and its studies.

SCIENTIFIC

The principal scientific applications for nuclear explosives are: production of heavy elements, neutron physics measurements, and geophysical research.[3] Although research in heavy element production continued during the year, it has not reached the point where a specific project can be considered.

Important applications of nuclear explosives to scientific research occurred during the year under the weapons testing program (see Chapter 6—The Nuclear Defense Effort) and have proved the usefulness of the nuclear explosive as a tool for basic scientific research. For example, the Los Alamos Scientific Laboratory carried out several neutron physics experiments which added significant data to basic scientific knowledge. In addition, use of gamma rays from underground nuclear explosions for scientific research was suggested by the AEC's Savannah River Laboratory and research has begun on this possible new application.

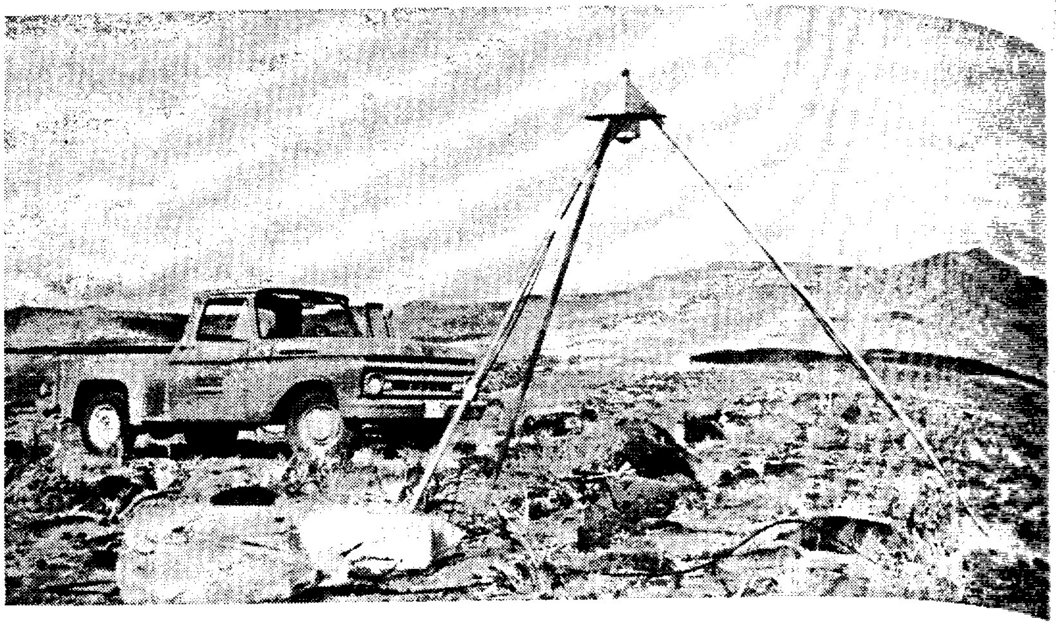
EXCAVATION PROGRAM

The program to develop a nuclear excavation technology, which was begun in 1962, continued to make steady progress during 1965. Significant activities included: the execution of a small-scale cratering experiment, called Palanquin; the acquisition of empirical data from cratering experiments in hard rock; the development of plans and diagnostic techniques for future cratering, device, and emplacement experiments; and progress in developing a theoretical understanding of cratering.

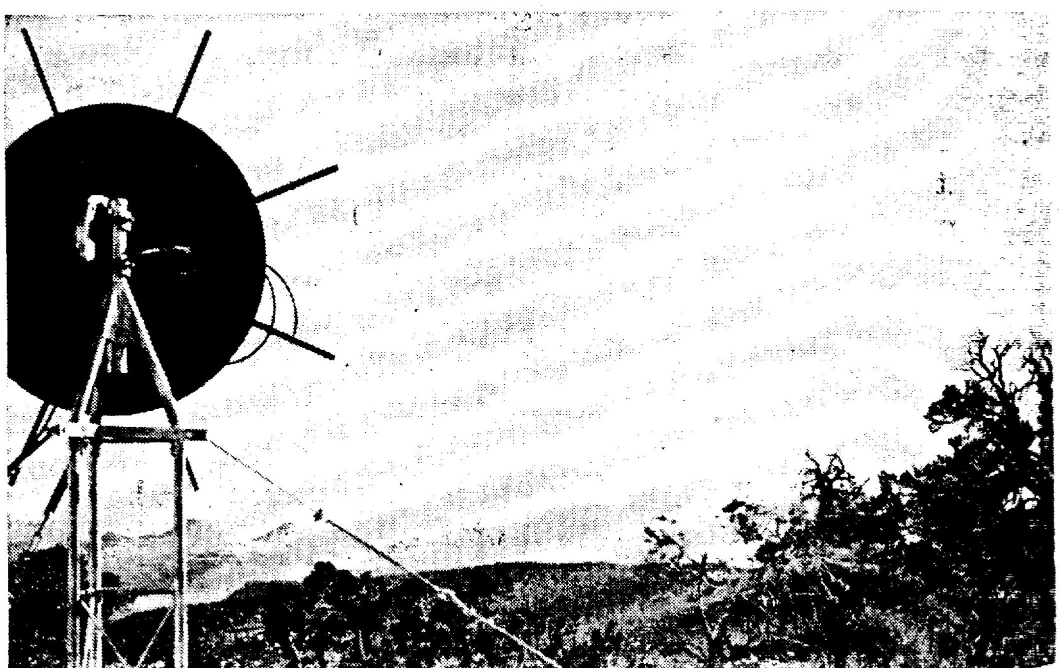
PROJECT PALANQUIN

Palanquin was a four-kiloton excavation experiment in a hard, dry rock. It was detonated at a depth of 280 feet on April 14, at the Nevada Test Site (NTS), and was the third small-scale experiment

[3] See pp. 171–172, "Annual Report to Congress for 1964."

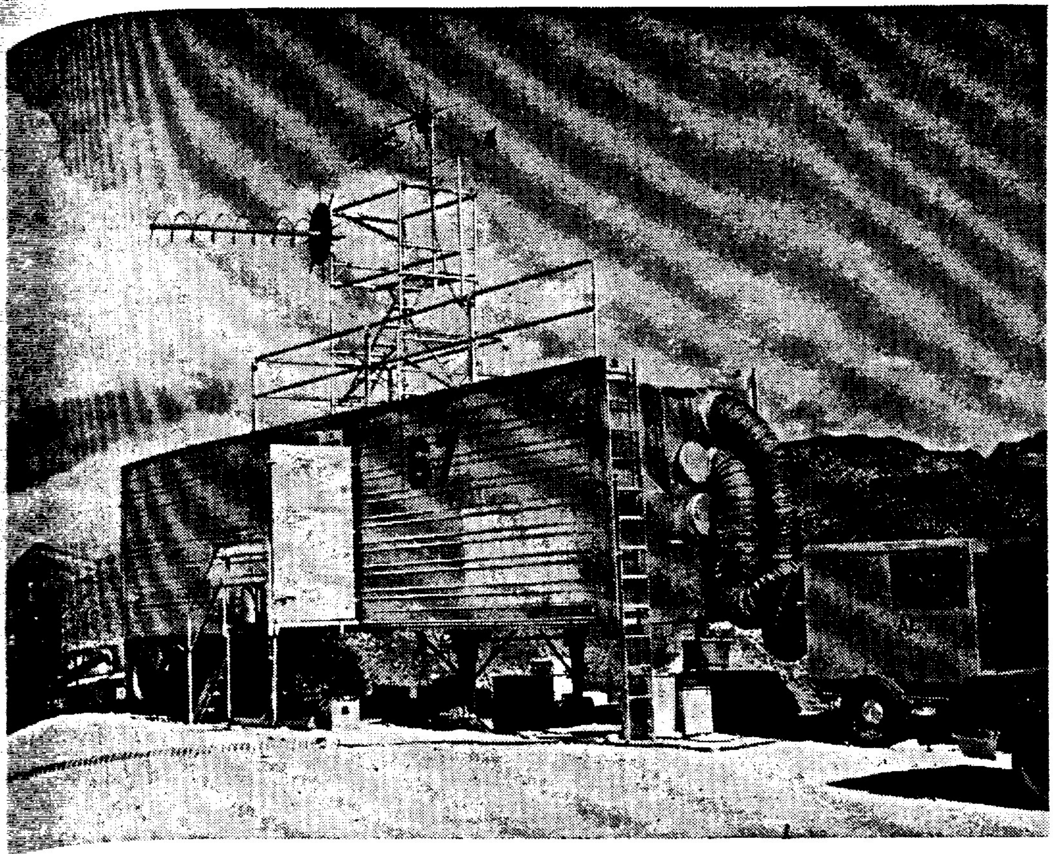


Gamma-Monitoring System. A versatile radio-linked system for spot monitoring ground and low-altitude gross gamma radiation over areas as large as 10,000 square miles has been developed by Lawrence Radiation Laboratory, Livermore. The system provides for transmission of radiation data, from unmanned sensor stations equipped with ionization chambers, by radiofrequency signal to a central data-recording station. Photo *above* shows an integrated unit containing both sensor and antenna. The conical cover is an integral part of the antenna and also acts as a roof for the ionization chamber. The chamber is also covered by a lead collimator. The sensor units are designed to operate unmanned and unattended as long as six weeks. Photo *below* shows a repeater station with its helical antenna directed at the data-collection trailer 15 miles away (see photos, *opposite page*). The 10-foot aluminum tower can be carried by one man and the antenna assembly by another. The system represents a decided advance in the technique of routine monitoring for airborne radioactivity and fallout patterns, such as might occur during Plowshare excavation detonations, and for meteorological phenomena. The system was first used in connection with the Plowshare Program's Sulky event of December 18, 1964.

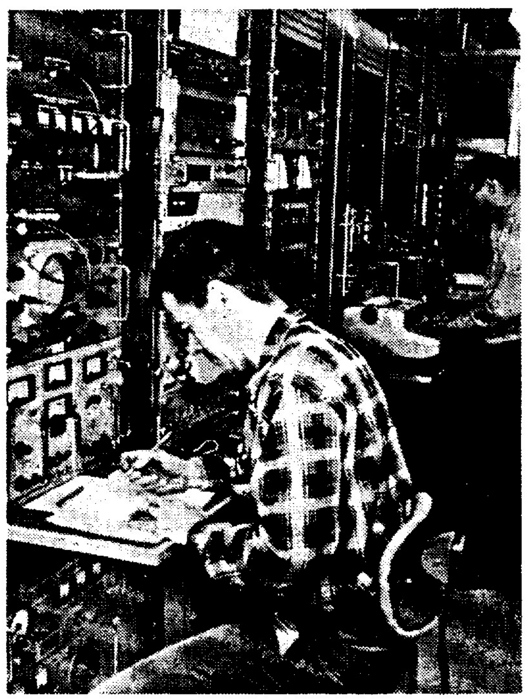


Gamma-Monitoring
sed. Signals rec
gamma radiation se
opposite page) are
control and data-
(shown *above*) whic
helical antennas of t
mitter assembly. A
is the power genera
the air conditioni
equipment. Photo
side the data trailer
(*left to right*) cont
quency-telemetry ap
storage and the data
circuitry for progran
rogating the senso
typewriter.

spot monitoring
large as 10,000
tory, Livermore.
nmanned sensor
gnal to a central
containing both
he antenna and
also covered by
unmanned and
station with its
vay (see photos,
ne man and the
advance in the
fallout patterns,
and for meteor-
with the Plow-



Gamma-Monitoring System—continued. Signals received from the gamma radiation sensors (see photos, *opposite page*) are received at the control and data-collection trailer (shown *above*) which is topped by the helical antennas of the receiver-transmitter assembly. At the extreme left is the power generator, at the right the air conditioning and heating equipment. Photo *at right* shows inside the data trailer. Vertical panels (*left to right*) contain the radiofrequency-telemetry apparatus, the data-storage and the data-readout, the logic circuitry for programing and for interrogating the sensors, and an IBM typewriter.



5009470

since 1963 in the excavation program.[4] The main purposes of this experiment were: (*a*) to determine the ability of emplacement techniques developed in 1964 to reduce the amount of radioactivity released to the atmosphere from a deeply buried cratering-type detonation, (*b*) to obtain basic cratering data, and (*c*) to document and study the dispersion and fate of the small amount of radioactivity released.

Atypical Crater Formation

A crater was formed with an apparent radius of 120 feet and a depth of 70 feet. The average lip height was 21 feet. However, the Palanquin cratering behavior was not typical in comparison to other nuclear cratering experiments in hard rock, such as Danny Boy (1962) and Sulky (1964). It appears that the crater was formed by erosion of the broken material rather than by its throw-out. This behavior resulted in the escape of a small amount of radioactivity which would normally have been filtered by the broken material in the dome. The explosive performed as expected, and peak pressures and initial ground motion were very close to predicted values. The extensive data collection program in operation during the experiment provided unprecedented detail on the behavior of the experiment, especially the early cavity history and the dispersion and fate of the radioactivity.

Exploration of Explosion Region

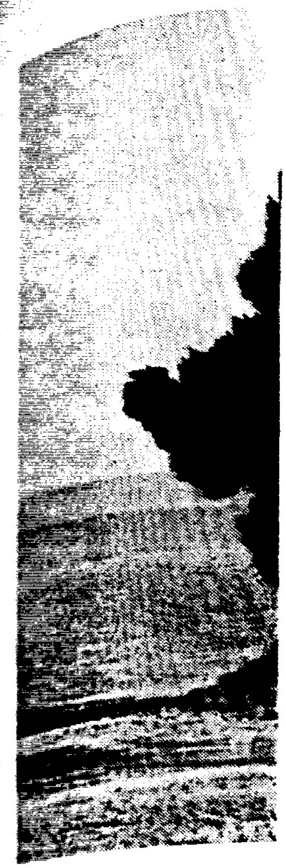
A post-shot exploration program, designed to obtain much needed data on the physical behavior of the emplacement technique used in the Palanquin cratering experiment, is underway. It involves mining a vertical shaft near the edge of the lip and extending a horizontal drift toward the underground region where the explosion occurred so that samples can be obtained and the shot-time cavity and true crater can be defined. The exploration will be completed in 1966.

OTHER CRATERING WORK

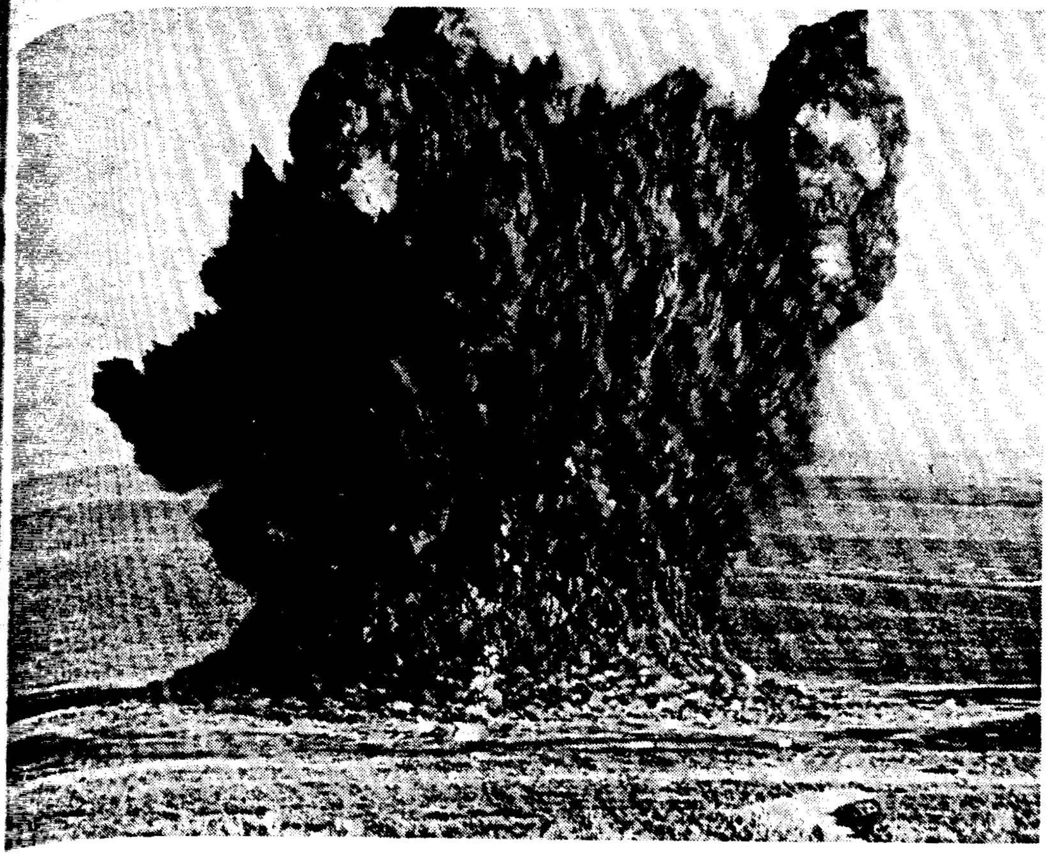
Pre-Schooner II Experiment

The Corps of Engineers' Nuclear Cratering Group (NCG) conducted a non-nuclear cratering experiment called pre-Schooner II on September 30, in southwestern Idaho, to provide cratering efficiency data for the type of hard, dry rock present at the site. This

[4] See p. 157, "Annual Report to Congress for 1964," and pp. 211–213, "Annual Report to Congress for 1963."



Cratering Experimen
ward use of nuclear
Corps of Engineers c
western Idaho. The
photographer, shortl
were detonated som
The resulting visible
feet across. The ex
basic hardrock crate
Schooner) nuclear ex



Cratering Experiment. On September 30, as a part of the studies leading toward use of nuclear explosives for excavation work, the AEC and U.S. Army Corps of Engineers detonated a high explosive (nitromethane) charge in southwestern Idaho. The photo *above* was taken, by an Idaho Falls Times-News photographer, shortly after the 85 tons of liquid nitromethane high explosive were detonated some 71 feet underground, 50 miles south of Mountain Home. The resulting visible crater, shown *below*, was an average 78 feet deep and 228 feet across. The experiment, pre-Schooner II, was one of a series to provide basic hardrock cratering data and design information for a proposed (Project Schooner) nuclear excavation experiment.

experiment which used 85 tons of the chemical explosive nitromethane, will be of use in further planning for the proposed Schooner nuclear cratering experiment, an event in the joint AEC-Corps of Engineers excavation program (see "Future Excavation Experiments" item later in this chapter). The pre-Schooner II experiment also provided an opportunity for Lawrence Radiation Laboratory, Livermore (LRL), and others, to obtain basic data on cavity growth and seismic effects for use in the research and development effort. In addition, several new experimental measurement techniques were attempted. Among these were determination of the volume of the debris cloud using a laser gun and measurement of air blast asymmetry with instruments suspended from balloons. Though neither of these was successful, both appear promising and will be attempted on future experiments.

Post-Dugout and -Sulky

Post-shot investigations of the 1964 Dugout and Sulky [5] detonations were carried out in 1965 by the Corps of Engineers to obtain basic engineering data related to slope stability and other properties of nuclear craters. This information is essential to the practical use of nuclear excavation for engineering projects. The data obtained on true crater-cavity boundaries and other parameters is being used by LRL in its research and development effort.

EXPLOSIVES DEVELOPMENT

One goal of research in the area of excavation development is to reduce to a minimum the amount of radioactivity released. From the standpoint of reducing the size of the area near a nuclear crater in which radioactivity falls out in potentially hazardous amounts and consequently which needs to be controlled to assure public safety, remarkable success has been achieved through developments over the past two years. In addition to reducing the amount of this radioactivity to assure public safety, it is necessary to limit the release of radioactivity in order to meet the requirement of the Treaty Banning Nuclear Weapon Tests in the Atmosphere, Outer Space and Under Water [6] that any underground nuclear explosion not cause radioactive debris to be present outside territorial limits of the country conducting the test.

[5] See pp. 157 and 159, "Annual Report to Congress for 1964."
[6] See p. 211, "Annual Report to Congress for 1963."

Developmental Goals

Two approaches to the goal of reducing the amount of radioactivity released are under development: (*a*) reducing the amount of fission yield in relation to the total yield of the explosive, and (*b*) special emplacement techniques to increase the amount of radioactive debris kept underground during the cratering process. Developments so far make it possible to produce explosives in a wide range of yields up to and including a megaton with no more than a few kilotons of fission, and plans were made during the year for further experiments to reduce the amount of fission products released during a cratering detonation.

Progress Made

However, during 1965, chief emphasis was put on emplacement techniques with the extension of the results from the contained Dub (1964) experiment[7] to the cratering-type situation in Palanquin. A great deal was learned from the Palanquin experiment about emplacement techniques, pointing the way to modifications and refinements which can be tried on future experiments.

Progress was also made in the research and development effort at LRL in the chemistry and biomedical areas. Particular effort was placed on identifying substitute structural materials which are not activated, which have less hazardous radioactive products, or which have chemical transitions which make them less available biologically.

FUTURE EXCAVATION EXPERIMENTS

The program of experiments necessary to advance nuclear excavation technology to the point where it can be used in large construction projects has been described in past Annual Reports to Congress[8] and most recently by AEC Chairman Seaborg on January 5, at a hearing before the Joint Committee on Atomic Energy.[9] In January, funds were requested in the President's budget for fiscal year 1966 for the first experiment in this program, Project Schooner. Subsequently, the amount of these funds was reduced by Congress in view of an anticipated delay in execution of the experiment because of the planning and extensive approvals required. In addition, the results of Palanquin showed that further device tests and at least one other small-scale nuclear cratering experiment were needed in order to

[7] See p. 161, "Annual Report to Congress for 1964."
[8] See p. 161, "Annual Report to Congress for 1964."
[9] See footnote 1 of this chapter.

develop more advanced devices and emplacement techniques. Plans are now being made to conduct these experiments in 1966.

RESEARCH AND DEVELOPMENT

The understanding of those effects of nuclear explosions which can be used for peaceful purposes is becoming increasingly refined and sophisticated. Knowledge and theory of these effects begins with an understanding of the immediate results of the detonation, especially the different forms of energy released and their dynamics, and the immediate effects of this energy on the surrounding and often different geological media. An understanding is then sought of the complex transmissions of source energy into its ultimate effects.

Although a distinction can be made between those underground explosions which have the ultimate, apparent effect of leaving a crater and those whose effects are mainly contained underground, the sequence of events shortly after the explosion occurs is the same and the theory, understanding, and predictive capability for them has a common beginning.

In 1961 and 1962, this understanding was largely empirical, being based simply on the relations to each other of observed phenomena; such as crater size, cavity size, depth of emplacement of the explosive, and yield of the explosive.

DEVELOPMENT OF PREDICTIVE THEORY

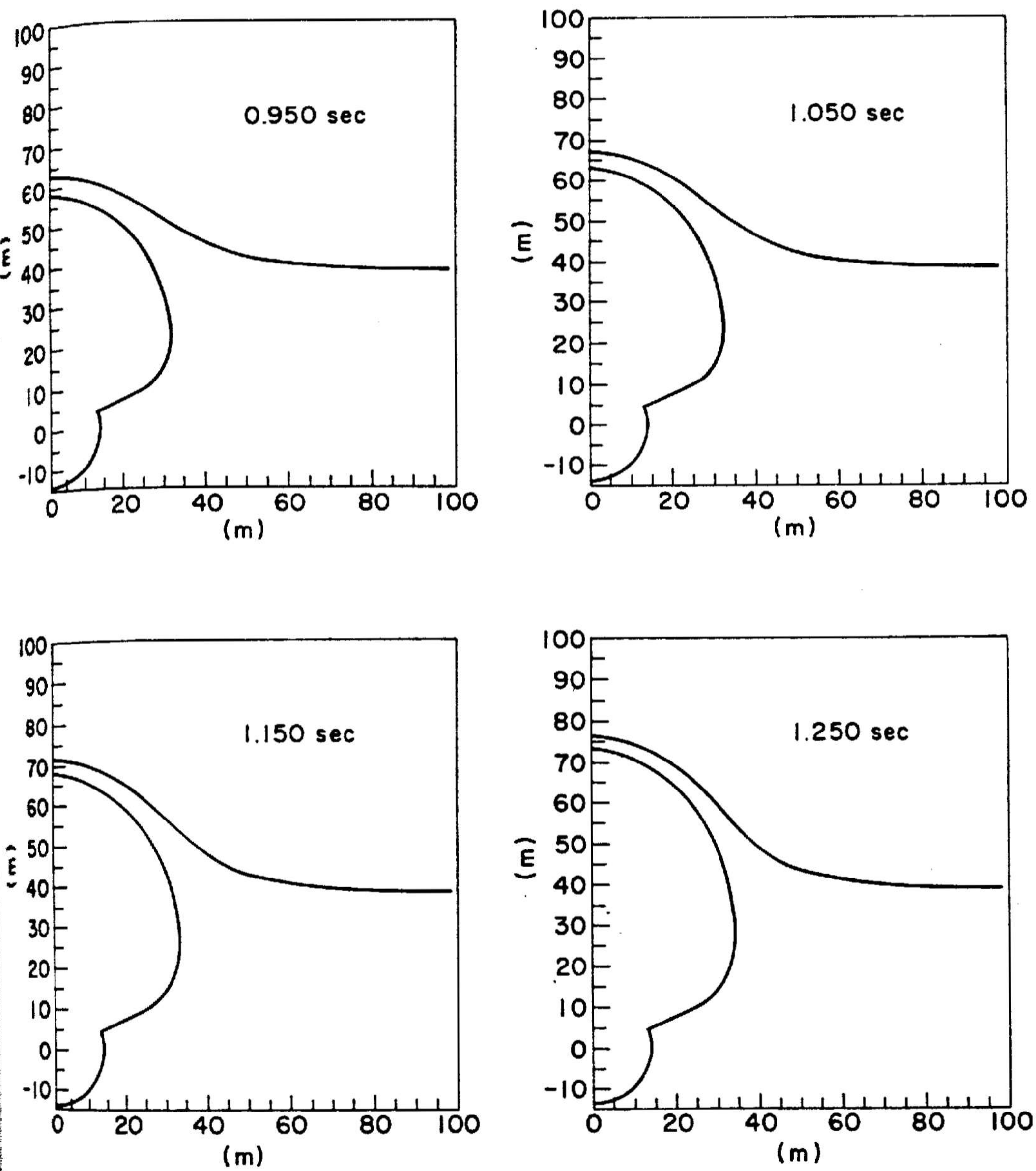
Beginning in 1963,[10] however, thousands of pieces of data have been collected from past experiments and organized with mathematical models so that the data can be handled in the large computers at the Lawrence Radiation Laboratory, Livermore. These calculational programs are then used to test the general theory by comparing its predictions for a specific situation against the observed results.

Computer Codes

A computer code, called SOC, developed in 1962, to calculate the effect of the shock wave and cavity expansion on earth materials, was refined and extended during 1965 with the data acquired from experiments in 1964, with the results of laboratory studies, and with further field measurements of rock properties. These calculations can now

[10] See pp. 211–213 and 219–220 of "Annual Report to Congress for 1963." For comparison, an example of the earlier empirical approach can be found on p. 246 of the "Annual Report to Congress for 1962."

predict with good agreement the measured results of detonations—the extent of explosion-induced fractures, cavity size, and earth motion. In the 1964 Salmon event of the Vela Uniform program, for example, measured peak pressure and peak velocity in the one to 600-meter range were within 20 to 50 percent of calculated results, time-of-arrival of the shock front was within 1 to 10 percent, displacement of the media at 300 meters was within 25 percent, and surface motion of the ground directly over the detonation was within 19 to 50 percent.



Cavity Formation. In a program to develop a detailed understanding and theory on which to base predictions for future experiments and applications, the AEC's Lawrence Radiation Laboratory, Livermore, has developed computer codes which can produce in a series of printouts, examples of which are shown here, reasonably close approximations to the formation and growth of the cavity formed by a nuclear explosion. Note the asymmetry which develops as the cavity grows toward the free surface. These calculations accurately reproduce the cavities made by several high explosive and nuclear detonations.

Two additional codes, called TENSOR and PUSH, were under development during the year. TENSOR is used for much more sophisticated predictions of the response in two dimensions of the medium to the shock wave. Among other things, TENSOR allows accounting for many of the nonuniform responses of the medium at different points. PUSH is used to predict in a similar way the response of the media to the late-time gas acceleration phase of the explosion. These codes are extremely useful in predicting the results of cratering detonations. In early trials during 1965, these codes were successful in predicting results which compare with previously observed surface motion behavior. Further refinement of these codes will be undertaken using data from laboratory studies, from further postshot investigations to obtain such data as is still available, and from Plowshare and other experiments.

Measurements of the spectrum of the ground shock from the 1964 Salmon detonation, which were obtained from the Plowshare add-on experiment,[11] were analyzed during the year and compared with the claims for damage which have been received. Although measured ground motion was in good agreement with predictions, the large number of claims suggested that further research to isolate and define the factors—such as geology, structural practices, foundation characteristics, and seismic wave properties—which contribute to structural damage should be undertaken. This research presently involves the instrumentation of some appropriate structures in areas near the Nevada Test Site.

The existing computer codes used to predict fallout from underground nuclear detonations which release, or may release, radioactivity were improved, updated, and checked against measured results of past experiments. Among the improvements to the code is an individual treatment for each radionuclide considered and a pictorial representation of the integrated, infinite dose pattern [12] to be expected with the actual wind conditions that exist at the time of detonation.

LABORATORY STUDIES

One very important area of research in the Plowshare program is concerned with the properties of rocks, especially as these properties vary over the range of conditions from the natural state to those of dynamic deformation at high pressure and temperature. Existing experimental techniques for determining these properties are often inadequate for Plowshare purposes and new techniques are developed

[11] See pp. 163–164, "Annual Report to Congress for 1964."

[12] A definition of infinite dose and examples of fallout patterns are shown on p. 211 of the "Annual Report to Congress for 1963."

by which new measurements can be made. During the year, a new experimental technique was developed to determine the failure characteristics of brittle material under stress. Measurements of various types of rocks using this technique have been factored into the computer codes, discussed above, and have greatly improved their accuracy in predicting the extent of explosion-induced fractures, cavity size, and free field earth motions.

Significant results were produced during the year by studies of the size of particles in fallout. With the increasing emphasis on a detailed understanding of the behavior of radioactivity released from nuclear explosions, it has become possible to describe, for many radioisotopes, the amount of radioactivity released in cratering detonations according to the physical form of the radioactivity (i.e., gaseous, volatile, or solid) and to relate this, where applicable, to the size of the particle to which the radioactivity adheres. This situation can be contrasted to the previous practice of describing the gross percentage of radioactivity released in terms of the amount in the fallout pattern. This work is being extended to additional radioisotopes, is being factored into the computer codes discussed above, and is planned to be extended into consideration of the biological availability, or nonavailability in the case of chemically insoluble isotopes, of the radioactivity.

Another example of these laboratory studies is a very small-scale cratering detonation using two grams of high explosive or exploding wires in a plastic that has properties which simulate certain key properties or geological media. The transparency of this type of plastic, even with the shock wave passing through it, makes it possible to study and to make direct measurements of certain explosion phenomena. These results contribute to the evolution of explosion theory, provide data to improve computer codes, and suggest important phenomena to be studied in future full-scale experiments and ways to make measurements of these phenomena.

CONTAINED EXPLOSIONS

Studies of the effects of contained underground explosions and the relationship of the effects to possible Plowshare applications continued during 1965. Results in the areas of the size distribution of rock fragments in chimney rubble and the distribution of fractures in the rock surrounding a chimney are of particular interest. The results of theoretical and empirical analyses of both these effects have been used in analyzing proposed applications.

5009478

POST-SHOT EXPLORATIONS AND STUDIES

Handcar Results

Post-shot investigations to date of Project Handcar,[13] a 10-kiloton explosion fired at a depth of 1,320 feet in dolomite on November 5, 1964, indicate that the gas generated was about the volume expected and did not cause the release of radioactivity or add appreciably to cavity size. The cavity radius was about 69 feet, slightly less than that expected for a similar shot in granite. A major purpose of the experiment was to study the effects of a nuclear explosion in a carbonate medium that yields a large volume of noncondensible gas upon decomposition.

Collapse of the cavity occurred shortly after detonation, but data from post-shot drilling showed that the collapse was terminated by the bridging of large rock fragments at a point above the shot point. Further postshot exploration is expected to provide more information on chimney height and collapse phenomena.

Surface motion measurements within eight miles were in good agreement with theoretical calculations. Mockups of gas well-head equipment at ranges of 950 and 1,250 feet from surface zero survived the explosion without detectable damage.

Salmon Results of Plowshare Interest

Salmon was a five-kiloton nuclear detonation, conducted by the AEC for the Advanced Research Project Agency of the Department of Defense, at a depth of 2,716 feet in a salt dome near Hattiesburg, Miss., in October 1964.[14] The Salmon cavity did not collapse, and postdrilling indicates that the cavity diameter is about 112 feet, very close to the radius predicted on the basis of Gnome results. That the cavity would hold fluids or gases under pressure was indicated by the fact that the absolute gas pressure within the cavity upon re-entry by drilling was less than ⅓ atmosphere.

OTHER RECENT RESEARCH RESULTS

In Situ Retorting Advance

Recent studies at Lawrence Radiation Laboratory, Livermore, permit the prediction of the approximate particle size distribution in a

[13] See p. 162 of the "Annual Report to Congress for 1964."
[14] See pp. 163–164, "Annual Report to Congress for 1964."

nuclear chimney. This information is essential to considering the technical feasibility of *in situ* retorting of the oil in the shale. With this knowledge, it will be possible to load a pilot-scale retort with particles which approximate those which would be found in a nuclear chimney and to study whether the heat flow around these particles would be sufficient to release enough oil to make the recovery economically attractive. Studies with the U.S. Bureau of Mines on appropriate oil shale formations in the western part of the United States for nuclear explosions were carried out during the year.

Water Resource Development

A summary and the principal conclusions of work which has been underway in the U.S. Geological Survey on water resource development applications for nuclear explosions were reported and published during 1965 as USGS Report No. TEI–857.[15] The current emphasis of this work is to locate and evaluate specific hydrological situations where nuclear techniques might be used.

Heavy Element Program

Plowshare program add-on experiments to weapons tests during the year studied the use of a heavier target (plutonium 242) and various improvements in design to increase the neutron flux in order to produce heavy isotopes, and possibly new elements. It was concluded that plutonium 242 would not be a suitable target and that substantial improvements in the flux through minor modifications were possible. A theory was evolved by the Los Alamos Scientific Laboratory which might lead to the selection of a better, more productive target than uranium 238 or plutonium 242.

---

[15] Available from Clearinghouse for Federal Scientific and Technical Information, National Bureau of Standards, U.S. Department of Commerce, Springfield, Va., 22151, price $4.

A wide variety of ethylene copolymer plastics have been formed using such monomers as carbon monoxide, sulfur dioxide, styrene, methyl methacrylate, vinyl acetate, acrylonitrile, allyl acetate, isobutylene, chlorotrifluoroethylene, trans-2-butene, methyl acrylate, isoprene, propylene, vinyl chloride, 1-butene, cis-2-butene, vinyl pyrrolidone, methyl vinyl ketone, and divinyl benzene. These have all been produced at room temperature. For the case of the ethylene-carbon monoxide copolymers, high molecular weight, high melting point products have been produced at 68° F. A crystalline melting point of 465.8° F. and an onset of decomposition at 482° F. were measured for a 50-percent carbon monoxide copolymer. These results indicate that several new plastics with important properties may be produced with radiation on an economical basis in the relatively near future.

The products have shown evidence of enhanced properties as compared to conventionally produced copolymers. Preliminary cost estimates indicate that the process should be economically attractive. These materials are part of a class of polymers which are produced in quantities of billions of pounds per year for the manufacture of molded plastic shapes, transparent films, and extruded forms.

RADIATION PROCESSED FOOD

The development of necessary technology for extending the shelf life of perishable foods and for reducing insect and bacterial contamination of foods through the use of low doses of radiation continued through 1965.

Status of Research and Development

Five species each of seafoods (clams, haddock, shrimp, Pacific crab, and flounder) and fruits (strawberries, peaches, grapes, lemons, and oranges) were originally selected for initial study in the early phases of the program. Radiation preservation of the five species of seafoods continues to show promise for ultimate commercialization, and other seafoods (such as sole, ocean perch, pollock, and cod) have been added to the program. Some of the fruits (such as lemons and grapes) selected initially, however, have failed to respond well to radiation treatment and have been replaced by more promising candidates (such as bananas, papayas, and mangoes). Approximately 13 varieties[2] of

[2] Seafood: haddock, cod, ocean perch, flounder, sole, pollock, clams, crab, shrimp, oysters, halibut, hake, and fresh water fish.

Radiation Preserva
be beneficially affec
conducted by the Ur
ripening and extend
control fruit (*top*)
irradiated for five

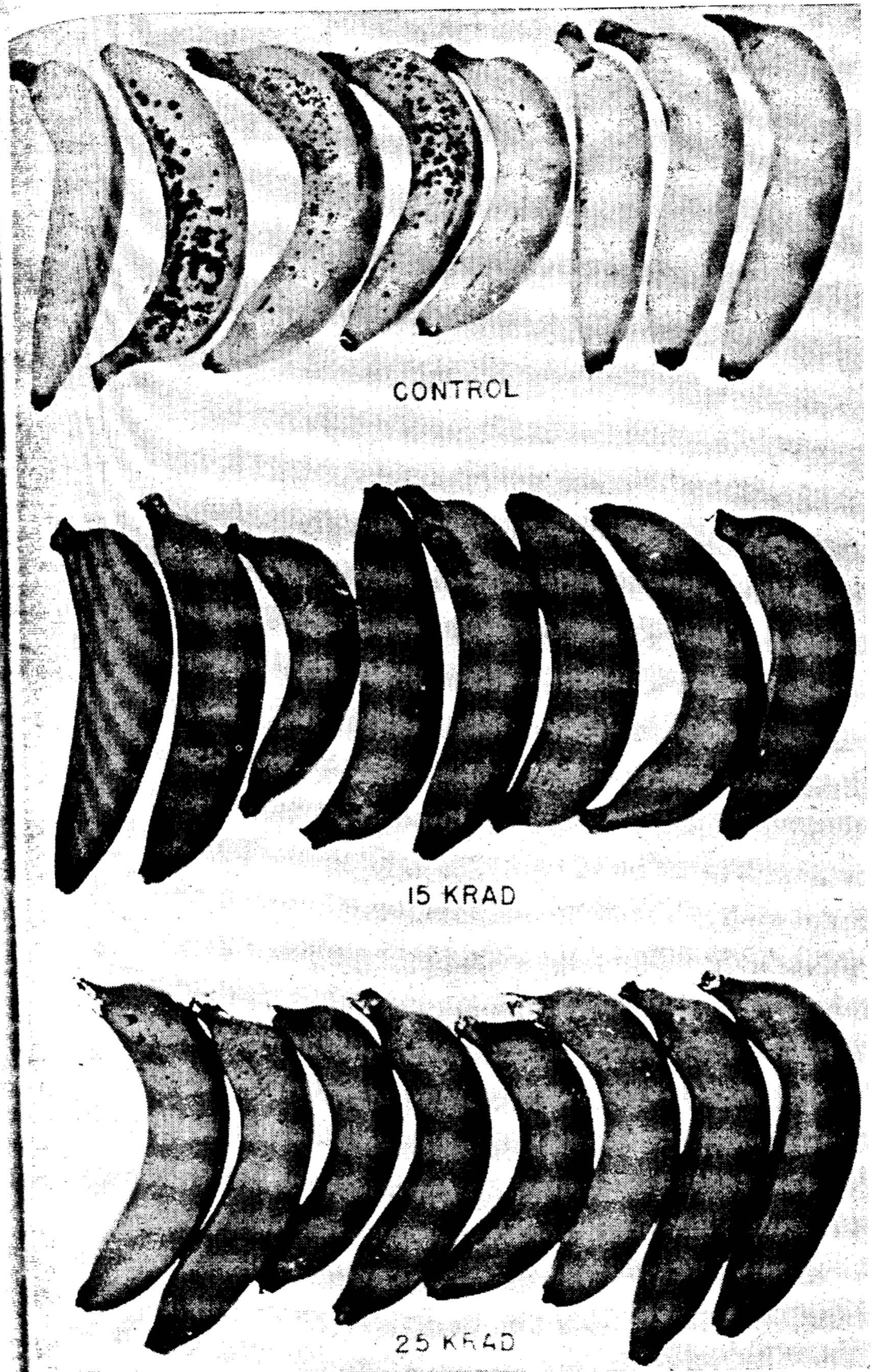
e been formed
oxide, styrene,
yl acetate, iso-
l acrylate, iso-
butene, vinyl
These have all
f the ethylene-
high melting
talline melting
F. were meas-
ese results indi-
erties may be
relatively near

perties as com-
inary cost esti-
ally attractive.
n are produced
manufacture of
forms.

ding the shelf
bacterial con-
ation continued

ip, Pacific crab.
es, lemons, and
he early phases
cies of seafoods
ation, and other
have been added
and grapes) se-
ell to radiation
andidates (such
13 varieties [2] of

crab, shrimp, oysters.



Radiation Preservation of Fruit. **Bananas, in particular, have been found to be beneficially affected by radiation from such sources as cobalt 60 in studies conducted by the University of California. Simple, inexpensive treatment delays ripening and extends the shelf life for two weeks. In the photo, the two-week-old control fruit (*top*) was a deep yellow; the irradiated fruit, which had been irradiated for five minutes at each of the two indicated levels, was still green**

seafood and 15 varieties[3] of fruits, vegetables, and grains are now under intensive study. Recent work on bananas, for example, indicates that a low dose of radiation will delay the time of ripening. Subsequently, ripening can be induced at will by the standard ethylene treatment. The resultant savings in spoilage losses through shelf life extension should have major economic significance.

Food and Drug Administration (FDA) approval of radiation processed foods for general public consumption is a prerequisite for commercialization. No new approvals were made during 1965; bacon, wheat and wheat products had been approved in 1963, and potatoes in 1964. A petition was accepted for consideration by the FDA on September 8, 1965 which involves the clearance of six species of fish (cod, flounder, haddock, ocean perch, pollock, and sole), in connection with the work supported at the Bureau of Commercial Fisheries, Gloucester, Mass., and sites.

International activity in this field is beginning to gather momentum, and the AEC is providing support in the form of personnel and a large cobalt 60 source to the International Center for Food Irradiation at Seibersdorf, Austria, where a program on radiation pasteurization of fruit juices is receiving major consideration.

Demonstration Programs

Because of the good progress being made, increasing emphasis is now being directed to activities for early commercialization of the food irradiation technology. Cooperative projects with private industry involve large-scale shipping, storage, and market tests, and construction and operation of pilot facilities. These Government facilities are being offered for limited use and testing to private industry. A phase concerned with consumer acceptance is also being planned.

An AEC solicitation to industry in May for participation in the food irradiation program met with an enthusiastic response. Some 20 commercial fish processing companies are now using the Marine Products Development Irradiator at Gloucester, Mass., for large-scale testing of several marine products under cooperative arrangement with the AEC and the Bureau of Commercial Fisheries. None were using the facility prior to May. Further cooperative Government-industry projects in both the fish and fruit fields are being arranged at the AEC's other large-scale food irradiators.

The AEC expects to participate in a cooperative industry-Army-AEC project for the design, construction, and operation of a meat

[3] Fruits, vegetables, and grains: strawberries, sweet cherries, plums, peaches, oranges, tomatoes (ripe), bananas, papayas, mangoes, figs, wheat, nectarines, prunes, pineapples and potatoes.

radiation sterilization facility to demonstrate the process as an industrial operation. A solicitation of interest of firms was made on September 24 proposing construction of a facility with private funds. More than 40 meat packers and construction companies showed an interest in such a project. The Army intends to purchase a significant portion of the facility's output. The AEC plans to provide a radiation source (either cobalt 60 or machine) and may also provide other assistance. Indications are that the project may proceed rapidly in 1966.

Irradiators

The use of four AEC research cobalt 60-irradiators [4] and the Marine Products Development Irradiator (MPDI)—a pilot plant facility—are contributing materially to the success of the food program.

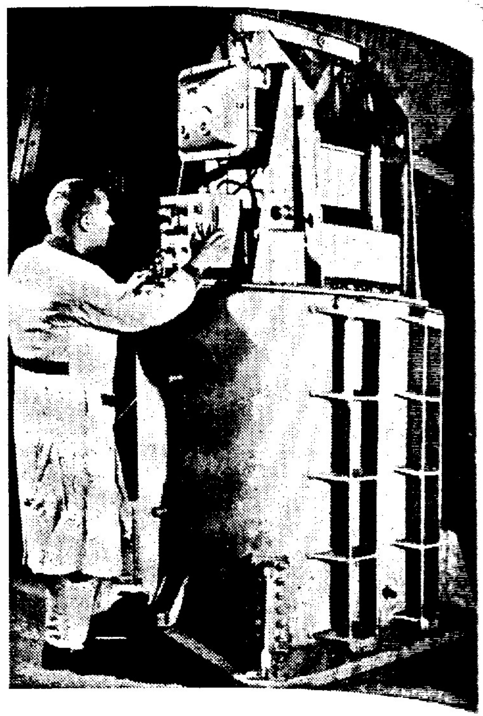
During 1965, the truck-mounted Mobile Gamma Irradiator (MGI) was completed by the Vitro Engineering Co. and will be sent to California for final checkout and field operation by the University of California. The mobile unit will be used for large-scale processing of fruit, including strawberries, bananas, and peaches, during the 1966 crop season.

The Grain Products Irradiator (GPI) located in Savannah, Ga., was nearing completion by the Vitro Engineering Co. and will be put into operation in late 1965. Although originally intended for insect disinfestation in grains, the GPI has drawn interest from processors of packaged mixes, cereals, and flours who have expressed a desire to cooperate in test irradiations of their products. The design of the irradiator has been modified to accommodate these uses.

Two shipboard irradiators were fabricated for the AEC by Nuclear Materials and Equipment Corp., Apollo, Pa. The first is to be on a U.S. Department of Interior fishing vessel working out of Gloucester, Mass. The second unit will be operational in early 1966, and operate in a similar manner out of Pascagoula, Miss. Irradiation of marine products as soon after catch as possible permits extended storage at quite low radiation doses. The 17-ton irradiators are versatile in their ability to handle a variety of products. A third such unit was ordered from Radiation Facilities, Inc., Lodi, N.J., and will be used cooperatively with selected segments of the poultry and fruit processing industries. Although the capacity of these shipboard irradiators is much less than the MPDI, they provide urgently needed additional units for scale-up testing beyond laboratory conditions, and are ideally suited for this purpose.

---

[4] See pp. 186–188, "Annual Report to Congress for 1964."



Preservation of Fish. Before any radiation-processed food can be made commercially available for general public consumption, it must be approved by the Food and Drug Administration (FDA). During September, the FDA accepted several species of fish for consideration. Photo on *left* shows fresh fish fillets being placed in the cobalt 60 irradiator at Massachusetts Institute of Food Technology in experiments to prolong the shelf life of fish by radiopasteurization. Photo on *right* shows a 30,000-curie, cobalt 60 on-ship irradiator being tested at Brookhaven National Laboratory. The 17-ton irradiator, which can handle 75 pounds of fish per hour at 200,000 *rads*, was developed at Brookhaven and constructed for the AEC by Nuclear Materials and Equipment Corp., Apollo, Pa. It will be used aboard fishing vessels so that fish can be processed immediately after they are caught.

Design work was begun in the fall by Nuclear Materials and Equipment Corp., on the Hawaiian Development Irradiator (HDI) to be located in Honolulu. Radiation preservation of tropical fruits for shelf-life extension, reduction of spoilage, and quarantine control will be done on a near-commercial scale when the HDI is completed in early 1967. Industry participation in the use of the irradiator will be invited.

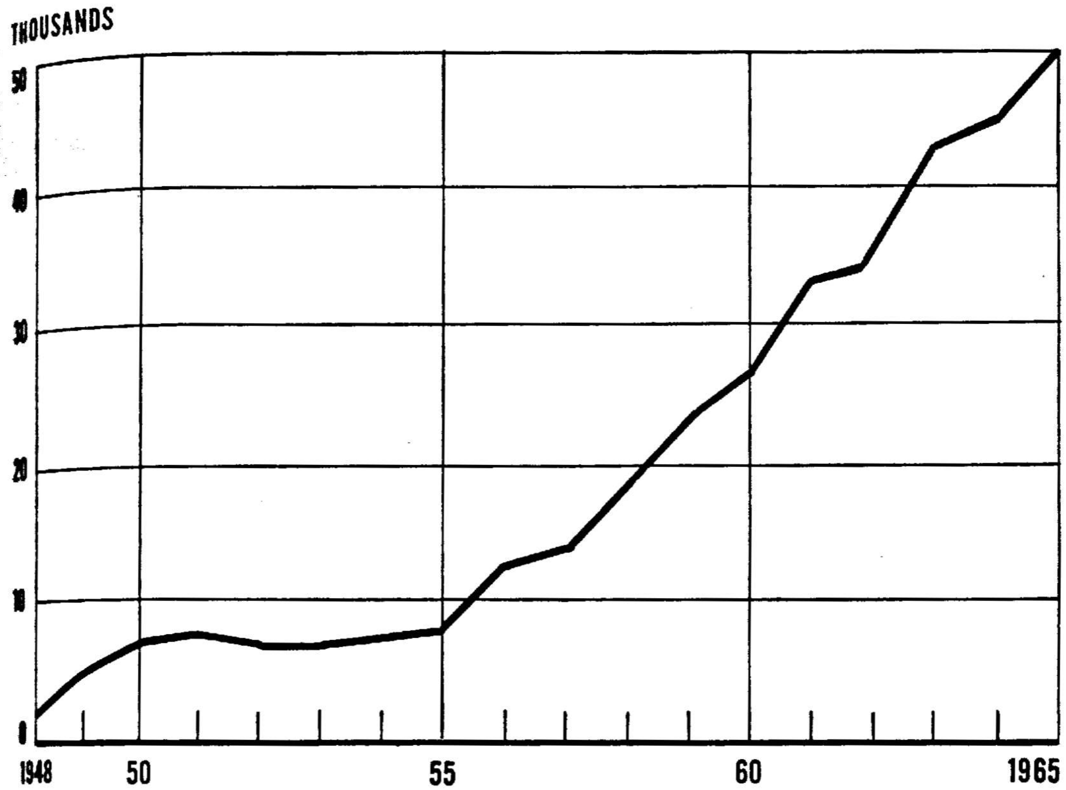
ISOTOPES SYSTEMS DEVELOPMENT

The development and demonstration of radioisotope-instrumented systems during the year showed promising substantial benefits in solving problems of direct Government and industry interest.

Nuclear Science Abstracts

AEC's semimonthly publication, Nuclear Science Abstracts (NSA), now in its 20th year, continues to be recognized internationally as the primary medium for announcement of the literature of nuclear science and kindred subjects. Of the approximately 50,000 abstracts carried in 1965, more than two-thirds were of journal articles and other short pieces of published literature, about 30 percent were of scientific and technical reports, and about 1 percent were of books. It is noteworthy that about 44 percent of the items originated outside the United States.

THE "EXPLOSION" IN NUCLEAR LITERATURE
(Items in Nuclear Science Abstracts)



Books and Monographs

To help meet the needs of scientists, engineers, and students for nuclear text and reference books, the AEC continued to foster the preparation of manuscripts for commercially published summary volumes which survey the main bodies of nuclear data. Nine AEC-sponsored books and monographs were published during 1965 (see Table 1, Appendix 6). Outstanding among these was the first volume, "Reactor Physics and Control," of the two-volume compendium, "The Technology of Nuclear Reactor Safety." Volume II is scheduled for publication early in 1966. In these volumes the lessons learned in 20